Bulletin 121

DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, SECRETARY

BUREAU OF MINES
VAN. H. MANNING, DIRECTOR

THE HISTORY AND DEVELOPMENT OF GOLD DREDGING IN MONTANA

BY

HENNEN JENNINGS

WITH A CHAPTER ON

PLACER-MINING METHODS AND OPERATING COSTS

BY

CHARLES JANIN

(Papers read at the Second Pan American Scientific Congress held in Washington, Dec. 27, 1915, to Jan. 8, 1916.)

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THE HISTORY AND DEVELOPMENT OF GOLD DREDGING IN MONTANA.

By HENNEN JENNINGS.

INTRODUCTION.

Many articles have been written on the general principles and details of gold dredging,[a] but it is not possible within the limits of this paper to recapitulate them, and it is thus necessary to assume some knowledge of this literature by the readers of this paper.

Although the purpose of this paper is to describe gold dredging in Montana, a brief mention of some early appliances used in New Zealand, Australia, and California may serve as a world-connecting link in our consideration of the development of gold dredging.

DREDGES EARLY USED IN NEW ZEALAND, AUSTRALIA, AND CALIFORNIA.

Spoon dredges operated by hand were tried in New Zealand on rich spots in the Clutha River with some success as early as 1865. A dredge of this kind is shown in Plate I, *A*. In 1870 a modification of the spoon, operated by steam and being thus a primitive steam-shovel dredge, was worked in New Zealand. Steam-shovel dredging was attempted in California as early as 1888 and 1893, and with some success in later years. The elevator gold dredge with endless bucket chain was put into operation in New Zealand in 1882. Plate I, *B*, illustrates a type of this dredge operated by current wheels. Plate II, *A*, shows a steam-operated dredge of this class, also started in 1882. In 1897 R. H. Postlethwaite, connected with the Risdon Iron Works, San Francisco, introduced the dredging practice of New Zealand into California. The first dredge built sank in the turbulent current of the Yuba. The second at Oroville, owned and operated by W. P. Hammon, proved effective and was the start in California of successful gold dredging. Since then the growth of the gold-dredging industry in California has been so rapid that the gold output from dredges in that State exceeds that of all other States in the Union, and, in fact, of any other country of the world, the value of the gold produced in California by dredging from 1897 to the end of 1914 having been about $71,000,000.

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[a] See "Selected Bibliography on Gold Dredging," p. 35.

The elevator-dredge development in California and New Zealand can be said to have comprised four stages, represented diagrammatically in figure 1,[a] as follows:

1, single-lift sluice dredge; gravel discharged directly to gold-saving sluice attached to main boat and projecting astern;

2, double-lift sluice; gravel elevated to trommel main deck, then sized and elevated by buckets or centrifugal pump to gold-saving sluice attached to main boat and auxiliary pontoon;

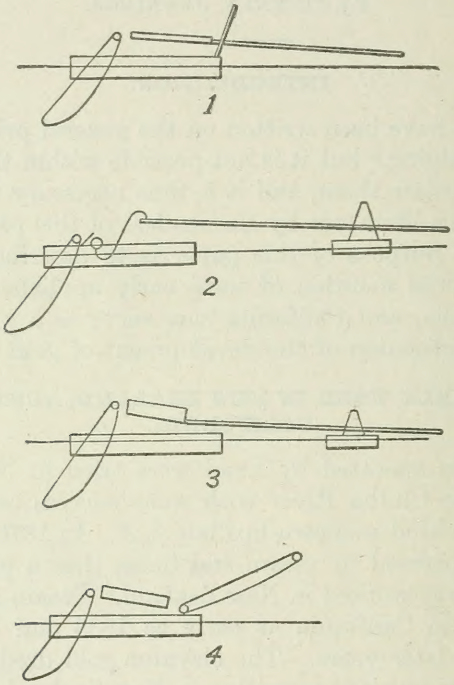

FIGURE 1.—Sketches showing four stages in development of elevator dredges in California and New Zealand.

3, single-lift sluice; gravel washed in trommel, then delivered to gold sluice attached to main boat and auxiliary pontoon; and

4, single-lift stacker; gravel washed in trommel or screen, fines distributed over tables charged with quicksilver, and over-size gravel piled in rear by stacker.

A report on the history and operation of gold dredging in the United States is now under preparation by the Bureau of Mines. Investigation of the technique of gold-dredging construction and operation will show that although California's advance and position in this line have been in keeping with her production, the part that Montana has taken is also important.

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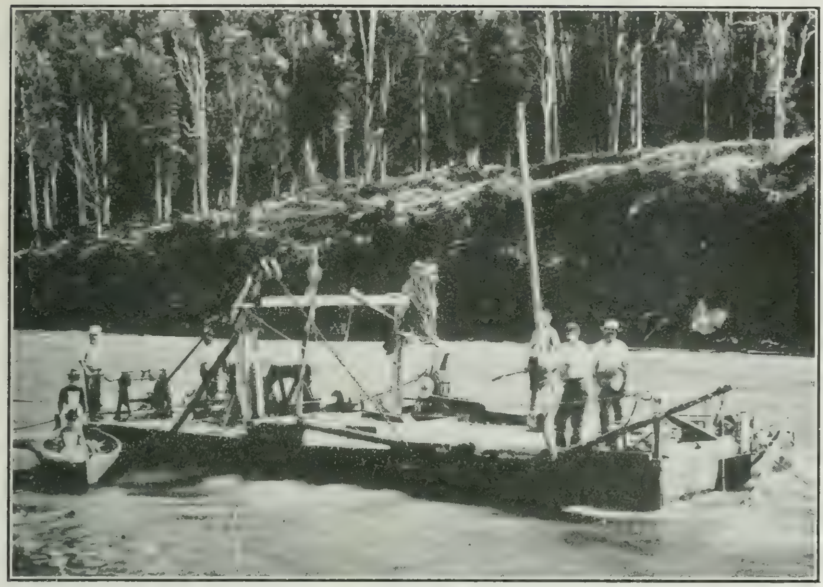
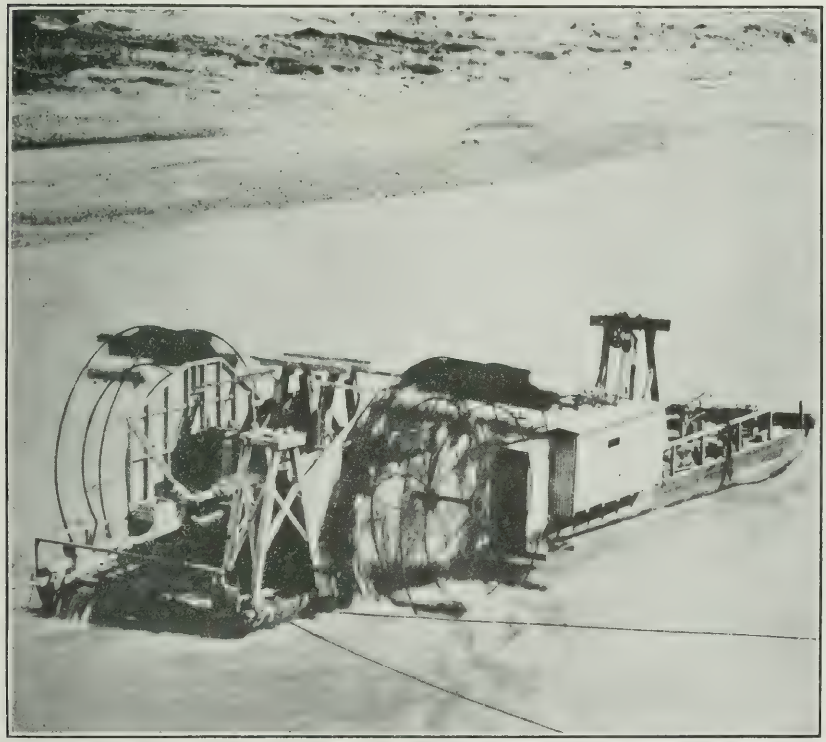
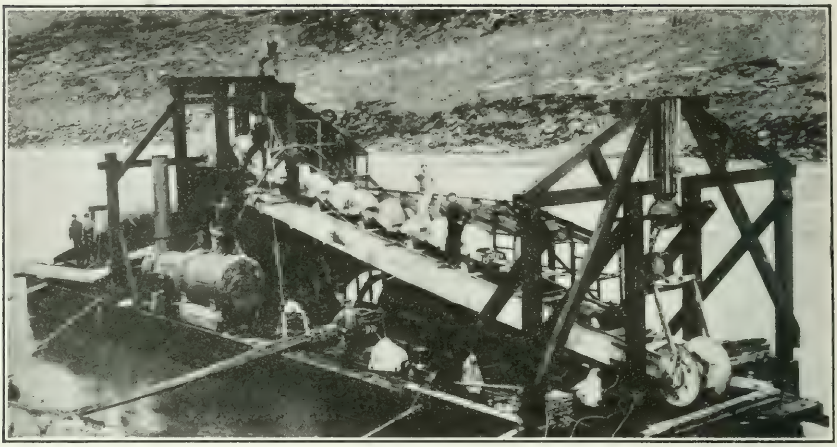
[a] Weatherbe, D'Arcy, Gold dredging in California, 1907, p. 49 shows same diagrams.



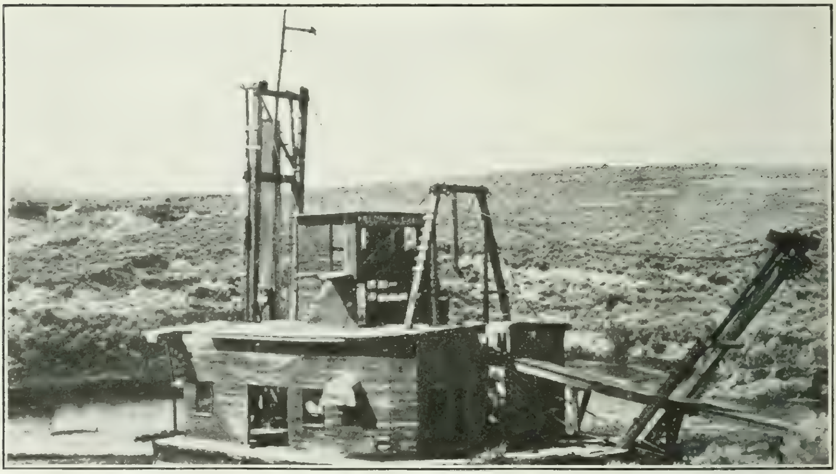
A. NEW ZEALAND SPOON DREDGE, 1865.



B. CURRENT-WHEEL DREDGE, NEW ZEALAND, 1882.



A. EARLY NEW ZEALAND STEAM-OPERATED, BUCKET-LIFT DREDGE, 1882.



B. THE FIELDING L. GRAVES, FIRST SUCCESSFUL BUCKET-LIFT DREDGE IN THE UNITED STATES, 1894.

EARLY GOLD DREDGING IN MONTANA.

In the gold production from dredging operations in the United States Montana ranks second, next to California, with a yield to the end of 1914 estimated at about $6,800,000.

The first successful bucket-lift dredge in the United States was that erected on Grasshopper Creek, Beaverhead County, Mont., near the town of Bannack, where the first capital of the State of Montana was situated in 1864–65.

The first production of gold in Montana on a large scale was that from bars lying both above and below the town of Bannack, on Grasshopper Creek, in the year 1862. The rich bars were exhausted in a few years, and the capital was removed to Virginia City in 1865, but some placer mining was conducted on a small scale spasmodically until dredging was undertaken. The data for the following account of the dredging operations on Grasshopper Creek in and about Bannack have been kindly supplied the author by one of the dredging company's superintendents, Mr. George R. Metlin:

DREDGE "FIELDING L. GRAVES."

The first dredge in Bannack was built for the Gold Dredging Co. by Harper & Reilling Bros. This project was started in 1893, and the dredge was ready for operation during the season of 1894. The dredge was electrically operated, using direct current from a power plant erected on the bank. It was a double-lift dredge, with small buckets having a capacity of about 1½ feet. The gravel was dumped into the grizzly, which removed the larger rocks, and the residue was carried to a sluice line on the top deck by a link-bucket elevator. The sluices from the boat were carried by cables suspended from towers on either side of the gulch. It was quickly found that this method of handling the machine was wholly impractical, and the dredge was rebuilt during the following winter and again put in commission the following season. This time the dredge was equipped with 5-foot buckets and a centrifugal gravel pump that delivered the gravel to sluices carried on outboard sluice scows. This was found to operate very successfully, and the dredges built on Grasshopper Creek after this period of experimentation followed very closely the lines laid down by this first machine. This dredge was known as the *Fielding L. Graves*, and operated continuously during the summer months until 1898, when the dredging ceased for lack of ground. Plate II, *A*, shows a view of the dredge at the present time.

DREDGE "MAGGIE A. GIBSON."

The next dredge installed was known as the *Maggie A. Gibson*. As originally constructed this was a suction dredge, having a circular revolving cutter similar to that used on harbor dredges, and a 16-inch centrifugal gravel pump delivering the gravel to sluice boxes carried on scows (Pl. III, *A*). This type of dredge was soon found impractical, and in the summer of 1895 or 1896 the dredge was also changed to the elevator bucket type. Afterwards it operated successfully for two seasons and was removed later to Alder Gulch, being the first elevator type dredge to be operated at Alder.

DREDGE "A. F. GRAETER."

During this same season the *A. F. Graeter* was constructed by the Bannack and the Gold Dredging Cos., and at the time was considered the last word in placer-mining dredges.[a] The dredge was steam-operated, and had 5-foot Bucyrus buckets with intermediate links between each bucket. The gravel was dumped into a grizzly, the coarser material being thus screened out and the residue pumped by a large centrifugal pump to outboard sluice boxes carried on scows. The dredge operated very successfully from the season of 1895 or 1896 up to the time that the dredging operations closed at Bannack. Plate III, *B*, a side view of the dredge and Plate III, *C*, of the bucket line, show the present condition of the dredge.

COAST CO. DREDGE.

The following season two more dredges were erected 4 miles below Bannack. One, known as the Coast Co. dredge, was a Bucyrus type dredge having identically the same size bucket line as the dredges mentioned above. This was the first single-lift type of dredge erected at this point. The buckets discharged into twin grizzlies. and the fine material passed over coco-mat tables into inboard sluice boxes which connected with out sluice boxes carried on the scow at the rear of the dredge. Upon starting, the dredge was found to operate imperfectly and had to be reconstructed and rebuilt during the winter of 1897. When reconstructed, one grizzly was placed longitudinally with the boat, screening the material into a sluice line, about 50 feet long, on the dredge; this sluice line discharged into another sluice line carried on scows at the rear of the dredge. This dredge was found to operate successfully and continued work until 1901, when it was closed down.

DREDGE "BON ACCORDE."

The same season there was constructed at the same point a dredge know as the *Bon Accorde*. This dredge was built by an English company that had operated drifting mines on the Grasshopper for a number of years and was the last dredge designed for Grasshopper Creek. It was of the same type of dredge as the Coast Co. dredge after the reconstruction, with the exception of the buckets, which were 9 feet. The sluices were hung over the rear of the dredge on a high A frame with bucket stays reaching from the prow of the dredge to the tail of the sluice line. The sluices could be swung out at different angles and receive gravel direct from the grizzly, which was placed at an elevation of about 50 feet above the deck. This dredge operated about 20 days. when owing to its top-heavy nature it tipped over and sank, thus ending the career of the Bon Accorde Mining Co.

The principle of the double-lift dredge and the dimensions of the *Maggie Gibson* are outlined in Plate IX (p. 10) and the appearance of the dredge when starting at Ruby is shown by Plate III, *A*.

The value of the gold taken out during the dredging operations at Bannack can hardly be determined at present. It has been variously estimated at three-quarters of a million to one and three-quarters million dollars. Probably the safest estimate is about one million dollars.

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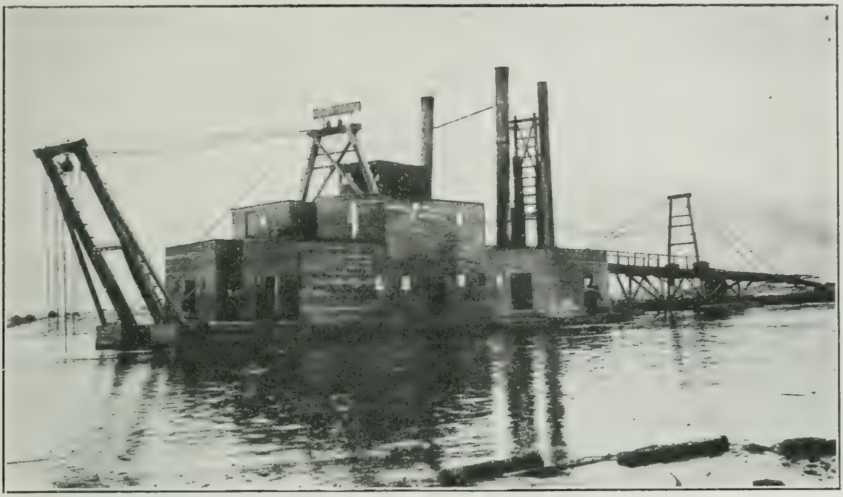
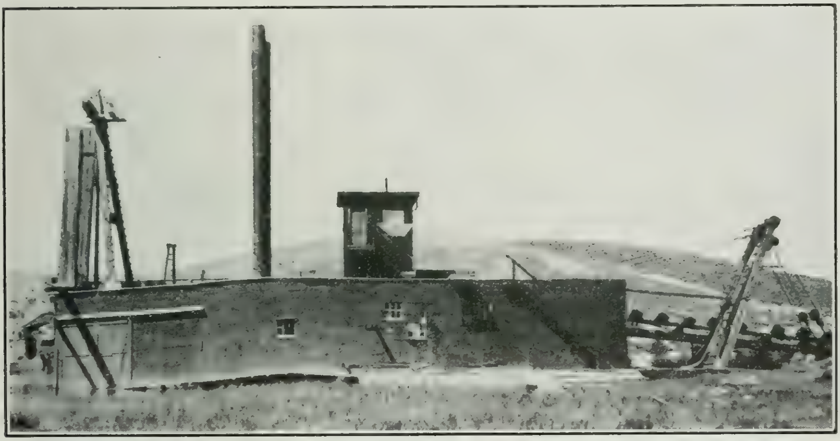
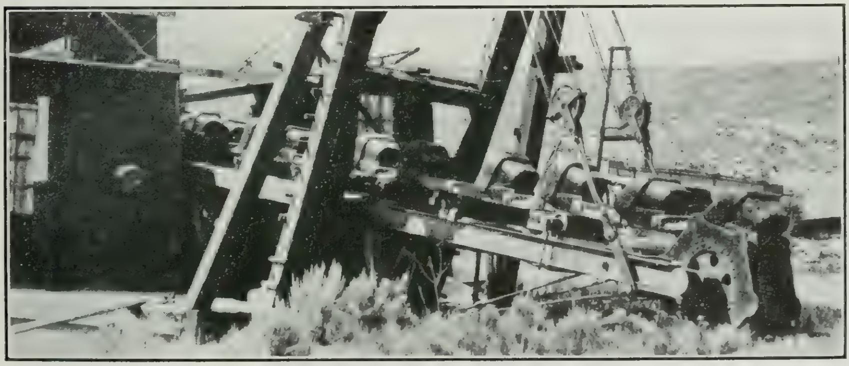
[a] Report of the Director of the Mint upon the production of the precious metals in the United States during the calendar year 1897. 1898, p. 174. Some of the specifications of the dredge follow: Hull, 102 by 36 feet; draft, 3 feet; endless chain of 36 buckets, each holding 5 cubic feet; links, 2½ feet; two locomotive boilers, 125 horsepower each; 75-horsepower sprocket and chain drive; weight of spuds, 11,000 pounds; total weight of dredge, 350 tons.



A. MAGGIE GIBSON AS FIRST WORKED AT RUBY, MONT., 1898; STARTED BANNACK, 1895.



B. SIDE VIEW OF A. F. GRAETER DREDGE USED AT BANNACK, MONT.; STARTED 1895.



C. BUCKET LINE ON A. F. GRAETER DREDGE.

A. BOWLDERS FROM ALDER GULCH, MONT.

B. ALDER GULCH, 3 MILES ABOVE ITS MOUTH.

GOLD DREDGING IN ALDER GULCH AND RUBY DISTRICT.

Alder Gulch empties into the Ruby River, a tributary of the Jefferson—a branch of the Missouri—and is in Madison County, Mont. Gold was found in Alder Gulch in 1862 in such quantity that its richness is renowned in the placer-mining history of this country; it has been estimated that in early days gold to the value of 40 to 90 million dollars was taken from the 16 miles worked, the upper 6 or 7 miles being steep and narrow.

The rush of miners to this place which was then far removed from railway communication entailed hardships and venturesome days, and the stories of robberies and vigilance committees in the early days of Virginia City, Mont., near this gulch, rival in interest those of California and Nevada.

After the cream of the gold had been skimmed by pan, rocker, Long Tom, and short sluices, the gulch was worked over again, and in some places for a third time by ground sluicing and other placer-mining methods; and finally endless-chain bucket-lift dredges, later described, are being employed to obtain the last remnants of the gold.

Some 4 miles of Alder Gulch has been dredged above its mouth and 2½ miles below it, the latter being in the low alluvial fan formed by the waters of Alder Gulch before uniting with the Ruby River. Up to the end of 1914, some 713 acres had been dredged, yielding about five and one-half million dollars.

The gravel dredged in Alder Gulch and its débouché lies on volcanic-ash beds which furnish a false bedrock of a sticky tenacious character. The depth of the gravel near the mouth of Alder Gulch is only 25 feet, the depth gradually increasing to 55 feet as work has extended toward the Ruby River. The gravel contains bowlders (see Pl. IV, *A*) larger than those usually found in the California fields, but where digging is more difficult the gold content is higher than the average. The hardest digging is where the bowlders have a compact clayish matrix.

Plate IV, *B*, illustrates the gulch about 3 miles above its mouth; Plate VI, *A*, shows the topography of the gulch near its mouth, with the Conrey company *No. 2* electric dredge at work. Plate V indicates the topography of the débouché of the gulch with the Conrey *No. 4* dredge at work, and Plate VIII shows a bank with hydraulic giants at work in front of No. 1 electric dredge.

RADIAL TRAVELING CABLEWAY.

Before dredging was undertaken by the Conrey Placer Mining Co. effort was made to work a section of the gulch at a point known as German Bar, about 4½ miles above its mouth, by the device known as the radial traveling cableway, with self-filling bucket. It was hoped that this device would excavate at low cost and deliver the material at sufficient elevation to permit the use of a sluice system of gold saving with ample length and grade. The essential parts of the device are well shown by Plates VI, *B*, and VII. A description of this device is given by Mr. Janin, page 53. It worked some 380,000 cubic yards at a cost of 27 cents per yard, which allowed little or no profit. The cableway was consequently abandoned after a trial of four years.

ORGANIZATION OF CONREY PLACER MINING CO.

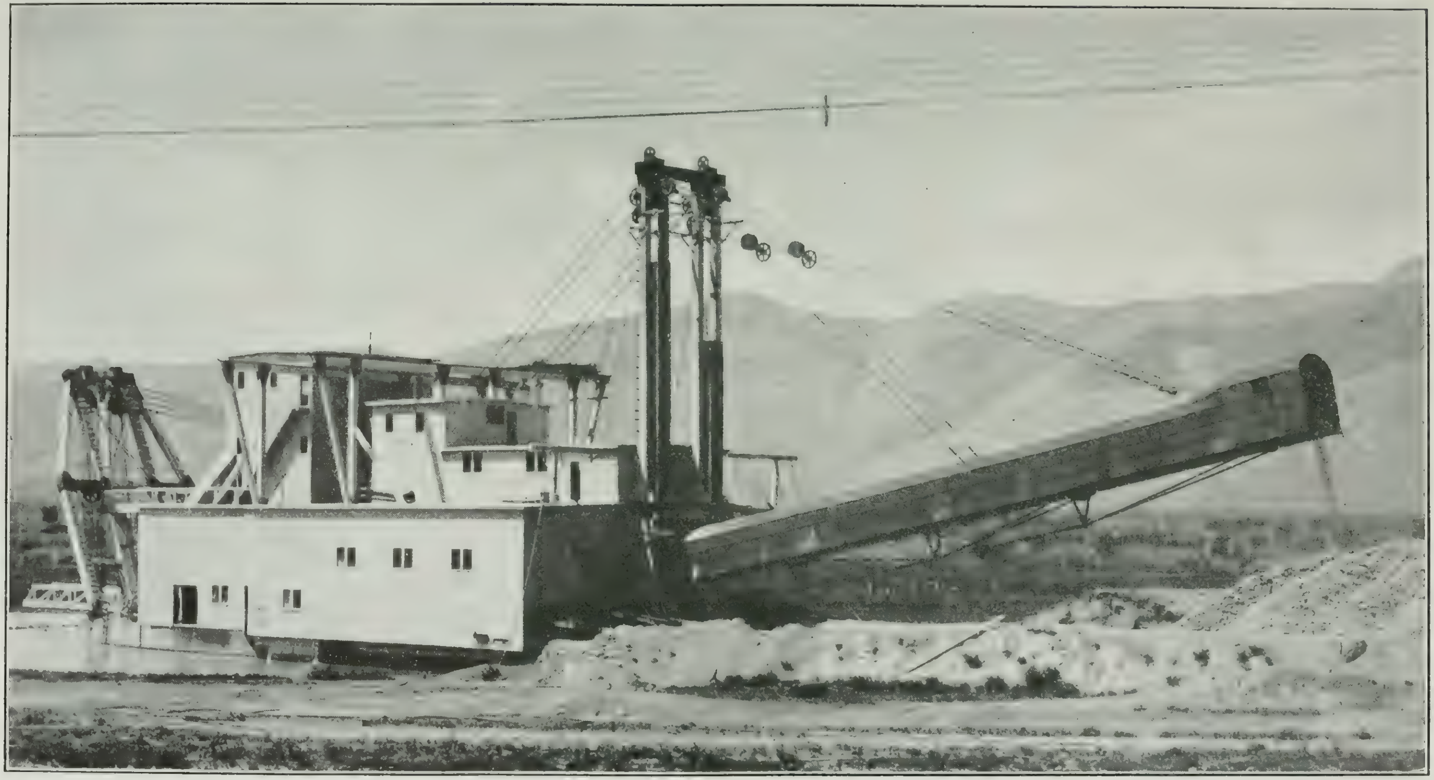
The Conrey Placer Mining Co. was formed in 1898 and the Poor Farm Co. in 1904. The Poor Farm Co. was absorbed by the Conrey company in July, 1915. In this paper all statistics are given as if only one company had existed, and that the Conrey.

The headquarters of the Conrey company are at Ruby, Mont., about 1½ miles from Alder, a branch terminus of the Northern Pacific and about 80 miles by rail from Butte. The headquarters have an elevation of 5,200 feet.

Mr. Gordon MacKay, well known as a capitalist and an inventor, in the initial stages of the company advanced the greater part of the working capital and controlled the stock of the company. He took a keen interest in all the mechanical details of the dredges and designed a centrifugal pump that has been worked with success and economy on one or two of the Conrey dredges. Prof. N. S. Shaler, dean of the scientific department of Harvard University, acted as consulting engineer and president until the time of his death in 1906. He was active in all the affairs of the company, and his geological attainments, energy, and personality were valuable in the obtaining of property, and of electrical power on the dredges. He was largely responsible for the continuation of the venture under trying conditions. This project brought Mr. Gordon MacKay and Prof. Shaler in close contact and knitted their friendship.

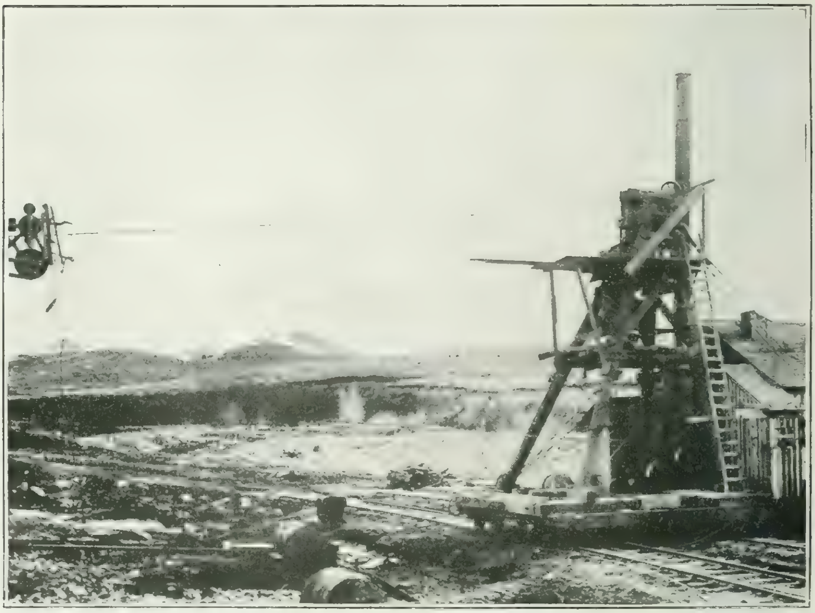
At his death Gordon MacKay willed almost his entire estate to the scientific department of Harvard University, but in such a way that the University could obtain the full income only by degrees. His very large interest in the Conrey company has given his estate, through dividends, retirement of stock, and interest on notes, something over a million dollars, which should eventually enrich the Harvard scientific department by this amount, and should be further swelled by the future earnings of the company.

The author, who has acted as consulting engineer since 1906, is under much obligation to Mr. W. P. Hammon, of California, and his assistants for generous information.

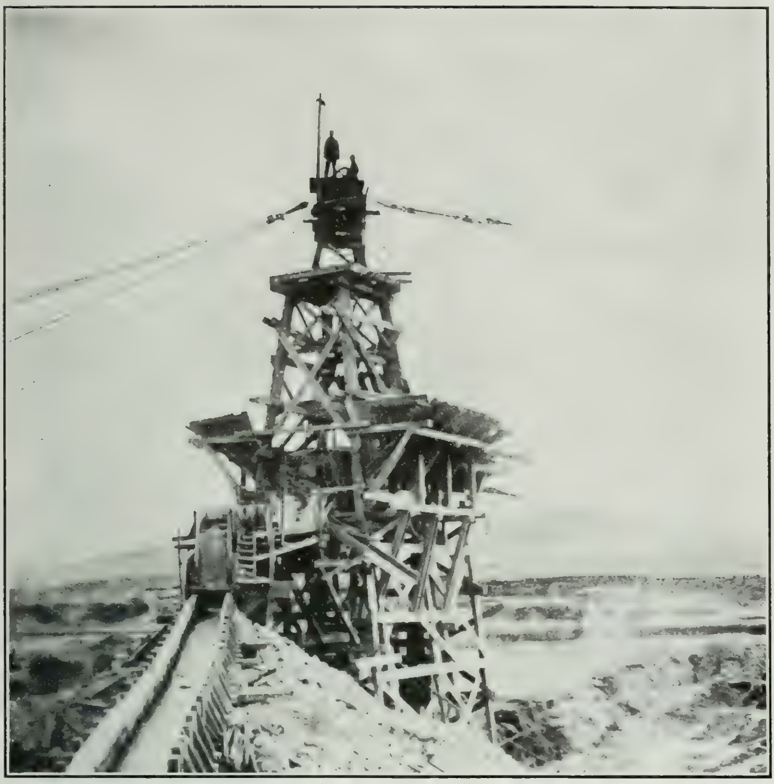


NO. 4 CONREY ELECTRIC DREDGE AT WORK IN ALDER GULCH DÉBOUCHÉ; STARTED 1911.

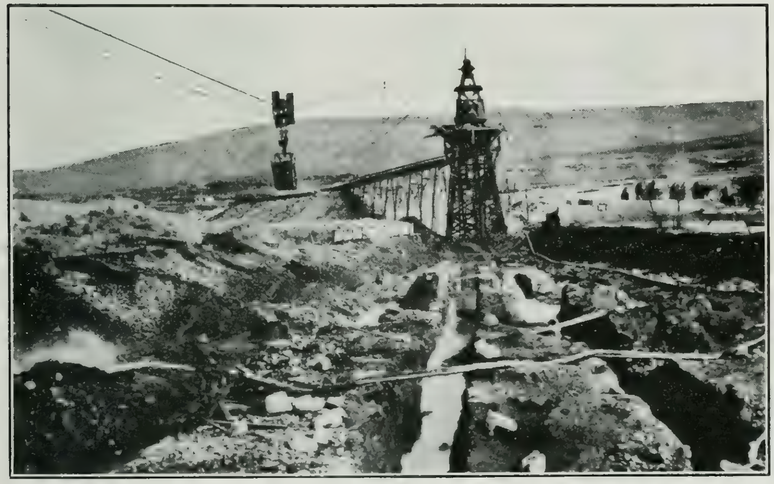
A. ALDER GULCH NEAR ITS MOUTH, SHOWING NO. 2 ELECTRIC DREDGE AT WORK; STARTED 1908.



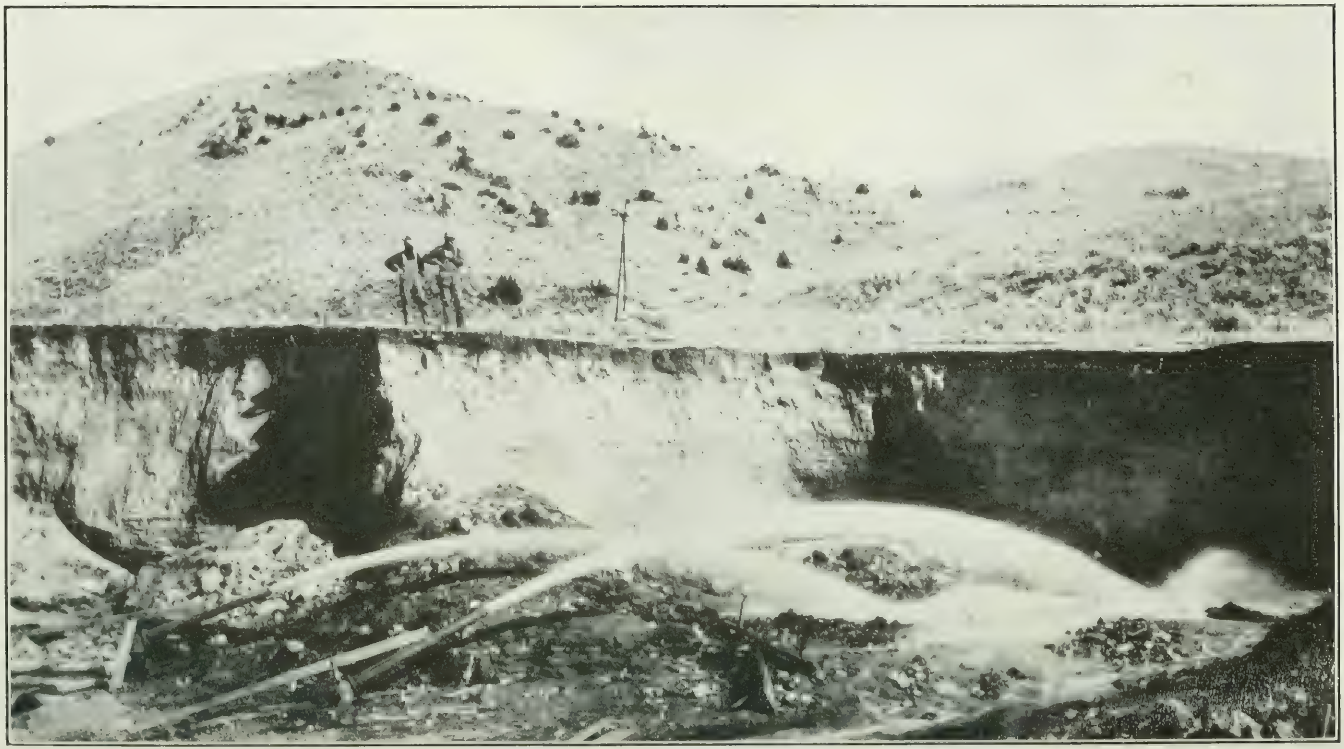
B. MOVABLE HEAD TOWER OF RADIAL TRAVELING CABLEWAY AT GERMAN BAR, ALDER GULCH, MONT.



A. PIVOT TOWER OF RADIAL CABLEWAY.



B. SELF-FILLING BUCKET TRAVELING TO PIVOT TOWER.



WASHING BANK IN FRONT OF NO. 1 ELECTRIC DREDGE AT ALDER GULCH, MONT.

In this enterprise the owners have raised no working capital through the stock exchange, although the outlay for dredges and other construction work has amounted to approximately $1,200,000; there has been no speculative dealing in shares, and new equipment has been financed through loans from shareholders, and repaid from operating profits. This venture has demonstrated that a sound mining property has no need of complicated finance or the machinery of the stock exchange.

The Conrey company, after abandoning the use of the radial traveling cableway, next tried to deal with the German Bar gravel in the year 1898. A little below the mouth of Alder Gulch a device known as the Hayward machine, a grab type of steam shovel, was tried and an outlay of some $30,000 was made. The device was unsuccessful and was in operation only a few months.

DETAILED DESCRIPTIONS OF CONREY DREDGES.

The Conrey company started their first dredging operations in 1899 and since that date have worked in the Alder Gulch district some 37,000,000 yards, with an average yield of about 16 cents per yard. The yardage cited probably represents about 80 per cent of the dredging done in Montana. This company has had in operation practically seven dredges, including the *Maggie Gibson*, three of which have been abandoned and four are now in operation. The three abandoned were the *Maggie Gibson*, and dredges *No. 1* and *No. 2*, which were single bucket-lift sluice dredges driven by steam. Of the present dredges at work, *No. 3* is a single bucket-lift sluice dredge driven by electricity, and the others are electric-driven bucket-lift stacker dredges of the type used in California.

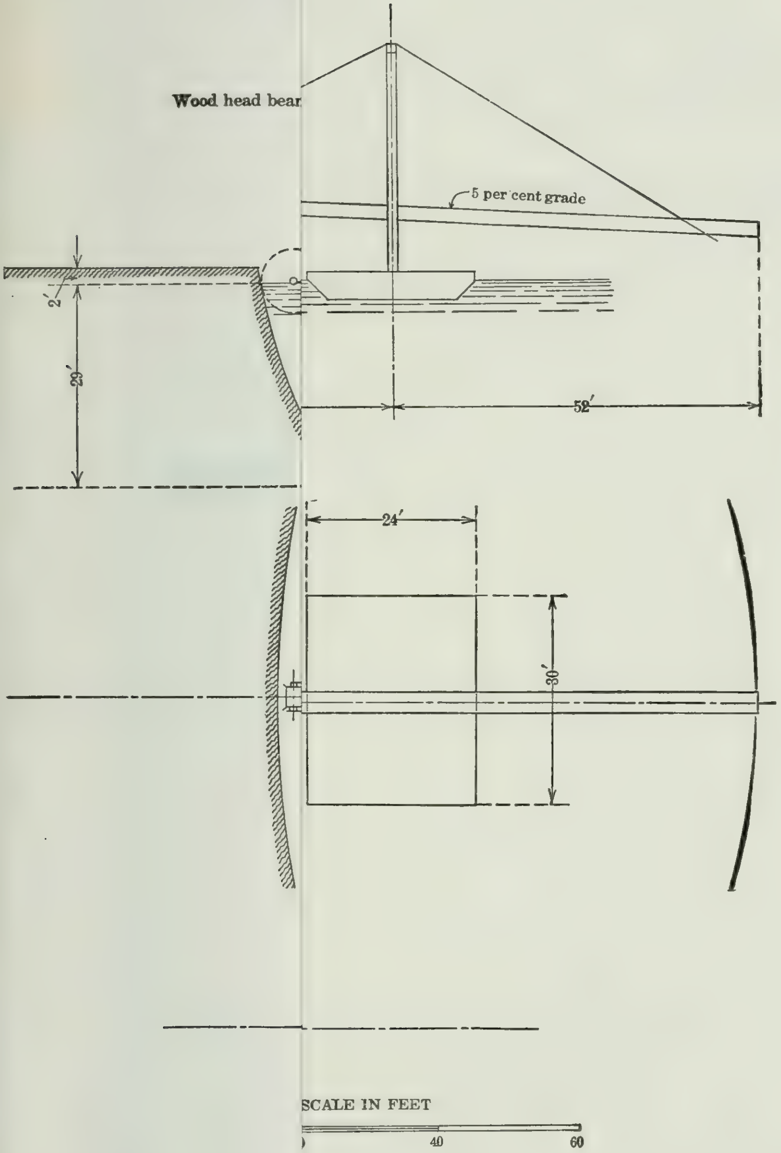
"MAGGIE GIBSON" DREDGE.

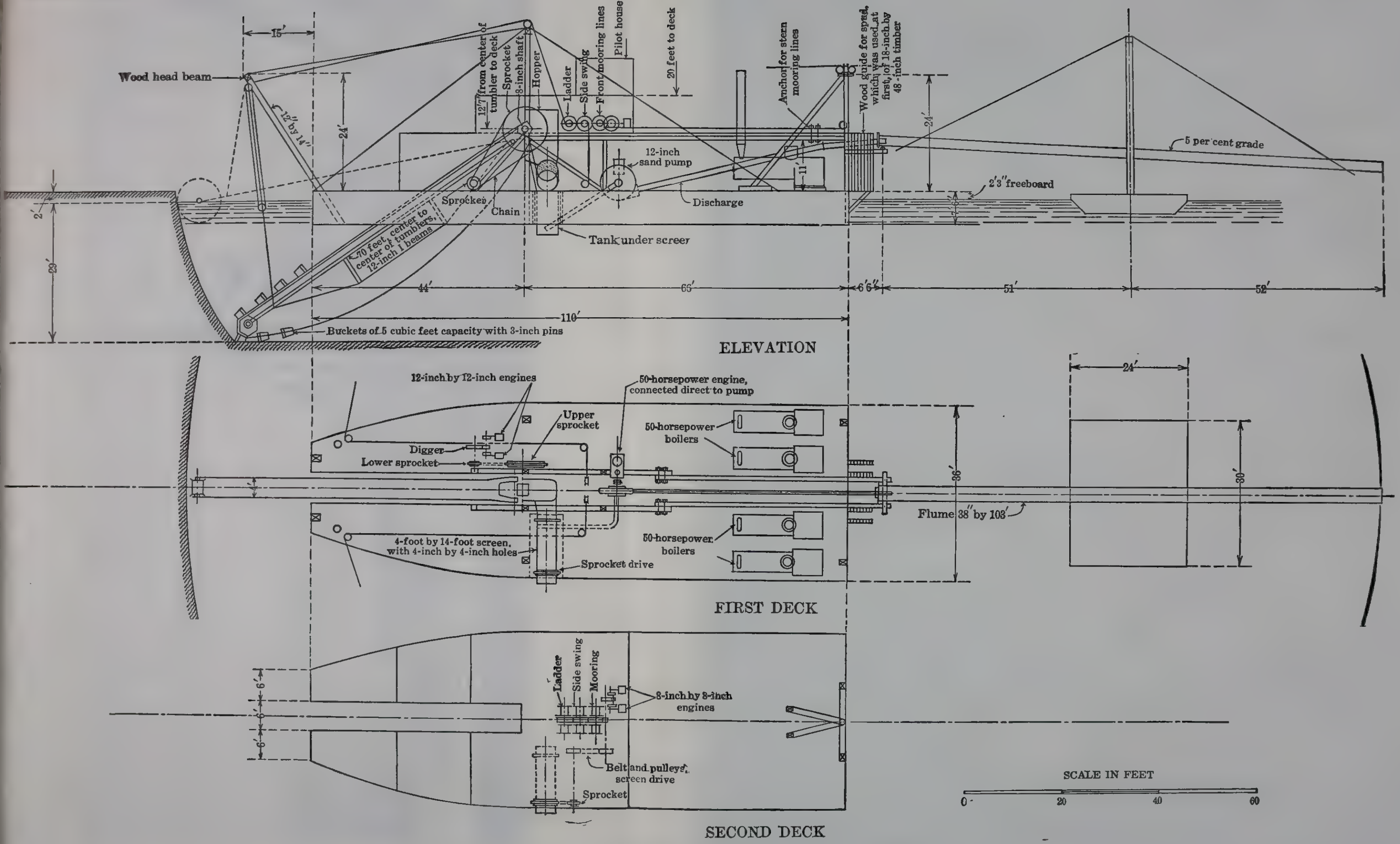
The *Maggie Gibson* was the first dredge in operation and was removed from the Bannack district in 1898, and was therefore not only one of the earliest bucket-lift dredges to operate in this country, but was also the first to be worked in two different localities. This dredge was not owned by the Conrey company, but its owners leased the ground from the Conrey company and paid the company according to a sliding scale of royalty charges for the gross gold recovered. Nearly a million yards was worked with the dredge, but four and one-half years was consumed in the task. The general appearance of the dredge is shown by Plate III, *A*. This dredge as an exponent of the dredging practice in the Bannack district naturally influenced the dredge construction of the Conrey company and was a strong factor in the development and perfection of the sluice type of dredge by that company. Plate IX shows a skeleton outline of its construction, indicating the manner in which it operated. It is known as a double-lift sluice dredge. The material excavated and elevated by the buckets was discharged into a revolving screen with large perforations so that all gravel larger than 4 inches in diameter was discharged overboard at the side of the dredge and the fines passed into a sump in the hull, from which a centrifugal pump elevated the material to a long sluice fitted with riffles and charged with quicksilver. The sluice was attached to an auxiliary pontoon, as shown in the figure. The dredge was operated at first by a spud-pivot system, which was also used at Bannack. Afterwards the spuds were discarded and replaced by a mooring-line system, which is later explained in detail. The gravel in the Ruby district was so much more difficult to excavate than at Bannack that the spuds which were sufficiently strong in the Bannack district were entirely inadequate for the work in the Ruby district.

STEAM DREDGES "NO. 1" AND "NO. 2."

Dredges *No. 1* and *No. 2*, single-lift, steam, sluice dredges, were started in 1899 and 1901, respectively, and were worked to the end of 1906. They differed little except in size. *No. 1* started with a chain of 41 open-connected buckets, holding 5 cubic feet. These were soon changed to buckets holding 7½ cubic feet. *No. 2* started with a chain of 41 open-connected 10-foot buckets. Power was transmitted by a sprocket drive. An excellent view of dredge *No. 1* is shown in Plate X.

Plates XI and XII give elevations and plans of *No. 1* and *No. 2* dredges. The table following gives, for seven dredges used in Montana, general dredge statistics and details of digging appliances and gold-treatment devices. It permits and facilitates easy comparisons and shows progressive development. The diagrams and table should make clear the principles and the details of construction of the *No. 1* and *No. 2* steam dredges.


Wood head bear
5 per cent grade
2′
29′
52′
24′
30′
SCALE IN FEET
40
60

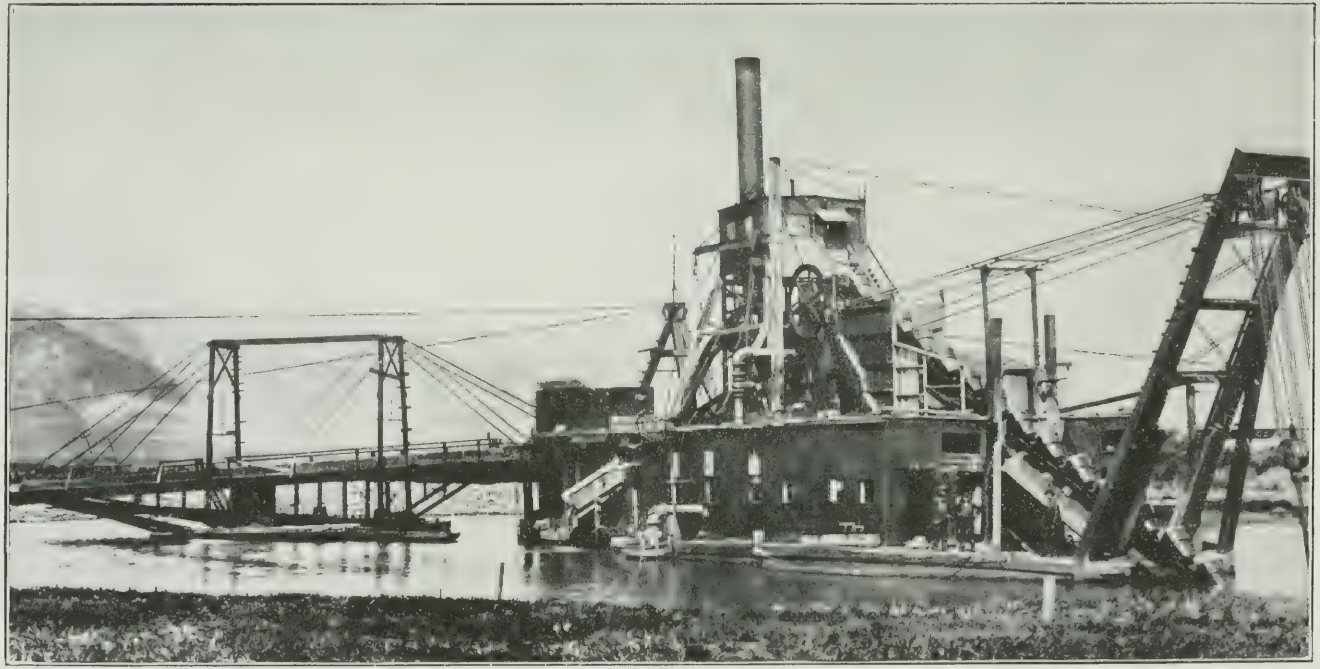


ELEVATION

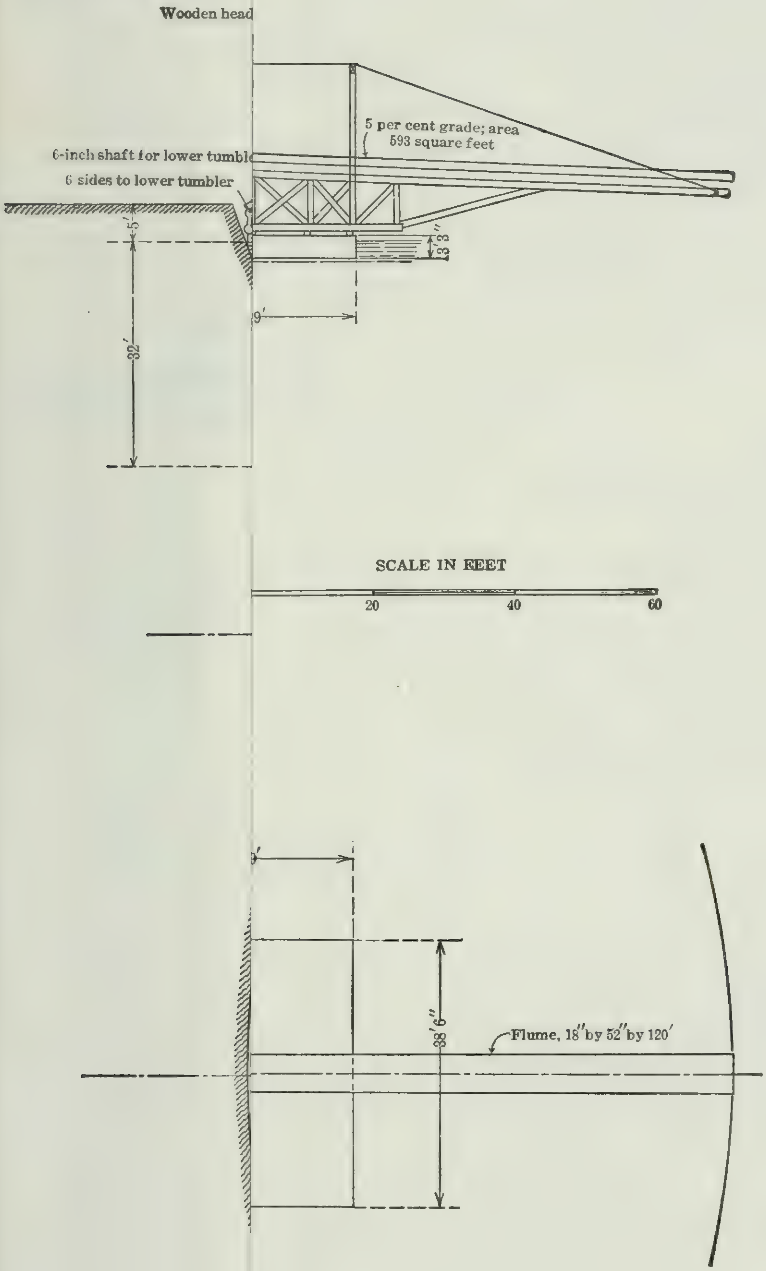
FIRST DECK

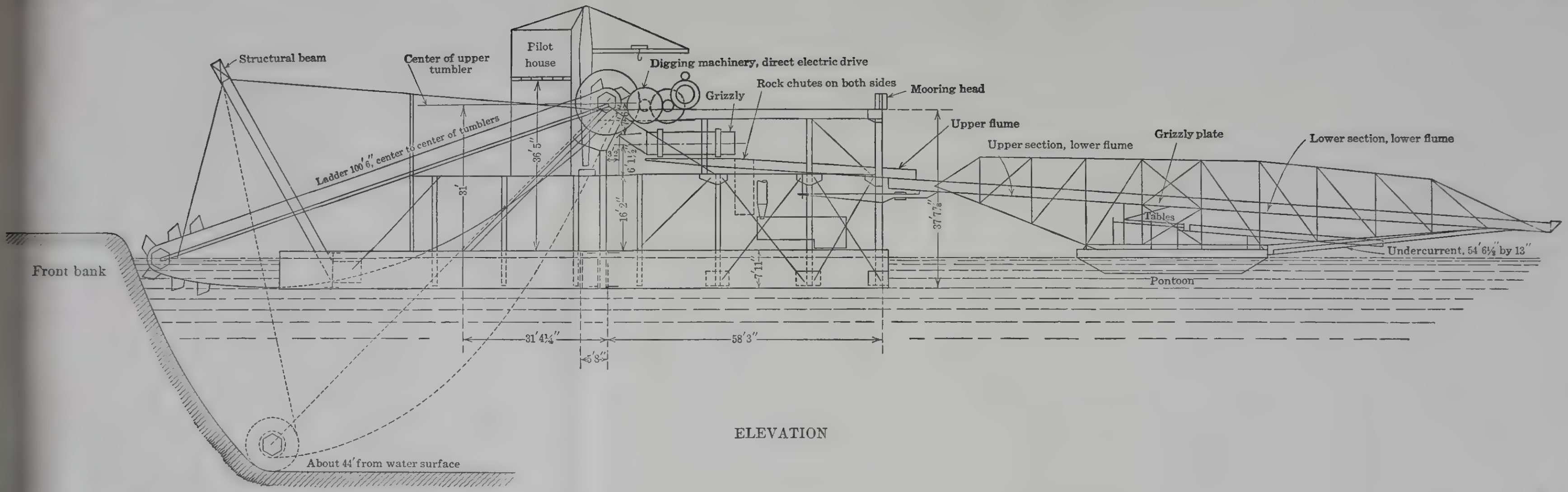
SECOND DECK

SECTIONS OF MAGGIE GIBSON DREDGE.

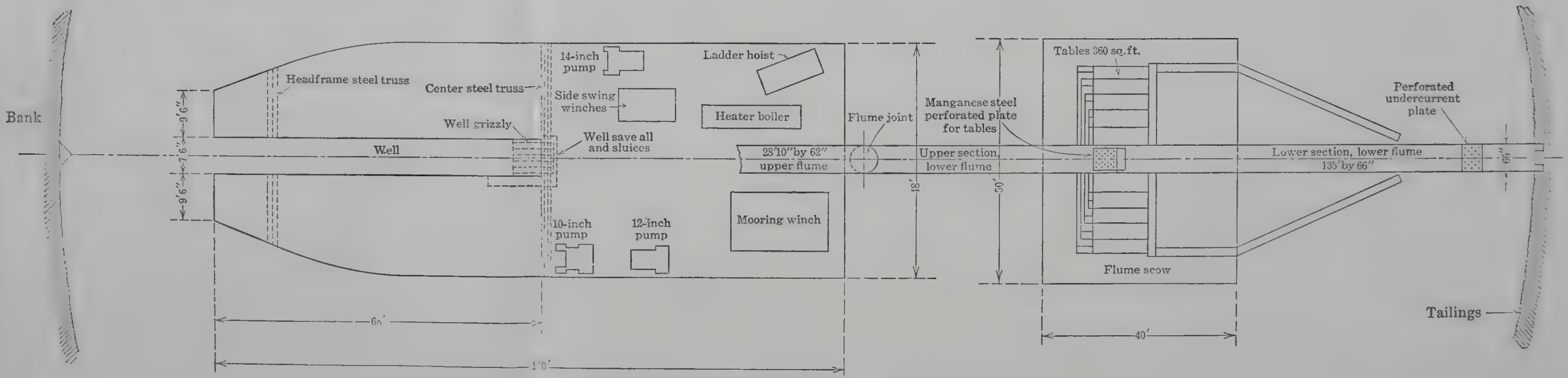


NO. 1 CONREY STEAM DREDGE; STARTED 1899.


Wooden head
5 per cent grade; area 593 square feet
6-inch shaft for lower tumbl
6 sides to lower tumbler
5'
13'3"
9'
32'
SCALE IN FEET
20
40
60
9'
38'6"
Flume, 18" by 52" by 120'


Structural beam
Center of upper tumbler
Pilot house
Digging machinery, direct electric drive
Grizzly
Rock chutes on both sides
Mooring head
Upper flume
Upper section, lower flume
Grizzly plate
Lower section, lower flume
Ladder 100'6", center to center of tumblers
Tables
Undercurrent, 54'6½" by 13"
Front bank
Pontoon
36'5"
31'
3'½"
6'1½"
16'2"
37'7⅞"
7'11"
31'4¼"
58'3"
5'3"
About 44' from water surface

ELEVATION



PLAN

SKETCH OF NO. 3 SLUICE DREDGE.

General statistics concerning dredges used in Montana.

Item.	Steam dredges.			Electric dredges.			
	Maggie Gibson.	Conrey No. 1.	Conrey No. 2.	Conrey No. 1.	Conrey No. 2.	Conrey No. 3.	Conrey No. 4.
Power used	Steam	Steam	Steam	Electricity	Electricity	Electricity	Electricity.
Date built	1896	1899	1901	1908	1908	1906	1911.
Type	Double-lift sluice	Single-lift sluice	Single-lift sluice	Single-lift table stacker.	Single-lift table stacker.	Single-lift table stacker.	Single - lift table stacker.
Anchorage	(a)	Lines	Lines	Spud	Spud	Lines	Spud.
Average monthly yardage worked, cubic yards.	27,000	41,360	52,520	96,270	62,709	82,415	300,000.
Hull dimensions:							
Draft	5 feet 3 inches	5 feet 4 inches	5 feet 9 inches	5 feet	5 feet 6 inches	6 feet	9 feet.
Length	110 feet	100 feet	110 feet	96 feet	102 feet	130 feet	150 feet.
Width	35 feet	44 feet	44 feet	44 feet	44 feet	48 feet	58 feet.
Depth	7 feet 6 inches	7 feet 6 inches	7 feet 6 inches	9 feet	9 feet	7 feet 11 inches	13 feet.
Pontoon dimensions:							
Length	30 feet	38 feet 6 inches	40 feet	None	None	50 feet	None.
Width	24 feet	35 feet	29 feet			40 feet	
Depth	4 feet	3 feet	3 feet 10 inches			3 feet 11 inches	
Stacker dimensions:							
Length	None	None	None	90 feet	85 feet	None	130 feet.
Width of belt				34 inches	34 inches		4 feet.
Motor drive							
Tailing height				Upper end 30 feet	Upper end 30 feet		Upper end 55 feet.
Dimensions of steel spuds:							
Length, feet	None	None	None	48	54	None	80.
Width, feet				3	3		4½.
Thickness, feet				2	2		3.
Weight, pounds				26,500	29,000		88,000.
Number				1	1		2.
Dimensions of wooden spuds:							
Length, feet	30	None	None	48	54	None	None.
Width, feet	1½			3	3		
Thickness, feet	4			2	2		
Number	2			1	1		
Horsepower:							
Bucket chain	45	60	73	100	100	150	550.
Trommel	5	6	8	30	30	10	100.
Pumps	40	79	147	160	160	175	285.
Winches	10	12	4	20	20	115	250.
Miscellaneous	None	19	16	70	70	10	50.
Total horsepower	100	176	248	380	380	460	1,235.

[a] Originally spud; changed to lines.

General statistics concerning dredges used in Montana—Continued.

Item.	Steam dredges.			Electric dredges.			
	Maggie Gibson.	Conrey No. 1.	Conrey No. 2.	Conrey No. 1.	Conrey No. 2.	Conrey No. 3.	Conrey No. 4.
Ladder data:							
Length, feet	70	82	95	69	80	100½ *a*	116.
Type	Queen truss	Queen truss	Lattice girder	Lattice girder	Lattice girder	Lattice girder	Plate girder.
Depth of digging below water, feet.	29	35	40	30	35	45	55.
Dimensions of tumblers:							
Upper tumbler—							
Distance above deck	12 feet 7 inches	24 feet 6 inches	29 feet 3 inches	25 feet 9 inches	29 feet 3 inches	31 feet	35 feet 6 inches.
Weight, pounds	2,000	2,000	4,050	8,970	8,970	8,970	16,000 to 25,300.
Number of sides	5	5	5	6	6	6	6.
Shaft diameter, inches	9	11	12	16	16	16	25.
Lower tumbler—							
Weight, pounds	3,000	2,500 to 3,075	4,600	5,800	5,800	5,800	18,000 to 19,800.
Number of sides	6	6	6	6 to round	6 to round	6 to round	6 to round.
Shaft diameter, inches	6	6 to 8½	10	13¼	13¼	13¼	15⅜.
Bucket-chain data:							
Type	Open link	Open link	Open link	Close connected	Close connected	Open link, later changed to close connected.	Close connected.
Drive	Sprocket	Sprocket	Sprocket	Belt	Belt	Gear	Gear.
Weight, pounds	40,000	104,000	125,000	169,000	225,000	297,000	357,500 to 415,300.
Capacity of buckets, cubic feet	5	5 to 7½	10	7½	7½	13 open, 9½ closed	16 to 17.
Number in chain	35	41	41	60	80	43 open, 80 closed	80.
Weight, pounds	750	750 to 1,500	1,850	2,594	2,594	2,900	4,468 to 5,191.
Pitch, inches	26	26 to 29⅜	31$\frac{5}{16}$	32¾	32¾	32¾	40.
Buckets dumped per minute	7	5 to 11	5 to 11	16	15	15	18 to 22.
Type	2-web	2-web	3-web	3-web	2-web	2-web	2-web.
Material	Steel	Steel	Steel	(*b*)	(*b*)	(*b*)	(*b*).
Hood and base, number of pieces	2	2	2	2	(*c*)	(*c*)	1.
Links—							
Weight, pounds	300	770	900	None	None	1,250	None.
Pitch, inches	26	29⅜	31$\frac{5}{16}$			32¾	
Number in chain	35	40	40			43	
Material	Steel	Steel	Steel			Steel	
Type	2-web	2-web	3-web			3-web	
Pins—							
Diameter, inches	3	3 to 4⅝	4⅞	4⅝	5	5	7 to 8.
Weight, pounds	50	50 to 130	155	168	184	184	520 to 495.
Material	Steel	Steel	Steel	Steel	(*b*)	(*b*)	(*b*).
Type	Double lug	Lock pin	Lock pin	Single lug	Single lug	(*d*)	Single lug.
Pin bushings—							
Type	Half circle	Full circle	Full circle	Full circle	Full circle	Full circle	Full circle.
Material	Manganese	Manganese	Manganese	Manganese	Manganese	Manganese	Manganese.

Trommel data:							
Length	14 feet	16 feet	15 feet 2 inches	35 feet	35 feet	18 feet	48 feet 6 inches.
Diameter, inches	48	46	48	51 to 72	51 to 72	61	98.
Type	Straight cylinder	Straight cylinder	Straight cylinder	Stepped cylinder	Stepped cylinder	Straight cylinder	Straight cylinder.
Drive	Sprocket	Sprocket	Sprocket and bevel gear.	Belt	Belt	Belt	(e).
Plates—							
Thickness, inches	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	1.
Material	Steel	Steel	Steel	(b)	(b)	(b)	(b).
Perforations	4 by 4 inches	4 by 4 inches	4 by 4 inches	$\frac{1}{2}$ to $\frac{3}{4}$ inch	$\frac{1}{2}$ to $\frac{3}{4}$ inch	$4\frac{1}{4}$ by 6 inches	$\frac{1}{2}$ to $\frac{3}{4}$ inch.
Dimensions of tables:							
Grade, per cent	None	None	None	$12\frac{1}{2}$	$12\frac{1}{2}$	12	$12\frac{1}{2}$.
Number				20	20	10	24.
Width, inches				30	30	30	30.
Length, feet				18	18	12	11 to $29\frac{3}{4}$.
Riffles (angles), inches				$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$.
Perforated plates						$\frac{3}{8}$-inch hole	
Pump data:							
Number	2	2	3	4	4	5	3.
Size and kind	4-inch water 12-inch gravel	10-inch water 14-inch water	10-inch water Two 14-inch water	3-inch water 8-inch water 12-inch water 6-inch sand	3-inch water 8-inch water 12-inch water 6-inch sand	3-inch water Two 10-inch water 12-inch water 14-inch water	4-inch water. 14-inch water. 16-inch water.
Make	Morris	Morris	McKay	Morris	Morris	Morris-Worthington.	Worthington.
Gallons per minute	4,000	6,500	8,100	6,700	6,700	12,500	12,000.
Main winch data:							
Length	12 feet	26 feet	26 feet	20 feet 1 inch	20 feet 1 inch	11 feet 10 inches	29 feet 10 inches.
Width	6 feet	16 feet	16 feet	4 feet 11 inches	4 feet 11 inches	8 feet 6 inches	7 feet 5 inches.
Diameter of drums, inches	16	16	16	16	16	30	24.
Number of drums	6	8	8	8	8	2	8.
Tail sluices:							
Grade, per cent	None	None	None	$12\frac{1}{2}$	$12\frac{1}{2}$	None	$12\frac{1}{2}$.
Number				2	2		12.
Length, feet				40	40		17 to 44.
Width, inches				48	48		48.
Riffles (angles), inches				$1\frac{1}{4}$	$1\frac{1}{4}$		$1\frac{1}{4}$.
Undercurrents:							
Grade, per cent	None	10	10	None	None	10	$12\frac{1}{2}$.
Number		1	1			2	12.
Length, feet		40	60			54	$7\frac{1}{2}$.
Width, inches		10	10			13	31.
Riffles—							
Material		Wood	Wood			Wood	Angles.
Size, inches		1 by $1\frac{1}{2}$	1 by $1\frac{1}{2}$			1 by $1\frac{1}{2}$	$1\frac{1}{4}$.
Perforated plates:							
Width of slots, inches		$\frac{1}{16}$	$\frac{1}{16}$			$\frac{1}{16}$	$\frac{1}{4}$.[f]

[a] Changed to 116 feet.
[b] Steel; later changed to manganese.
[c] Steel buckets in two pieces; manganese in one.
[d] Lock pin; later changed to single lug.
[e] Gear; later changed to belt.
[f] Holes instead of slots.

General statistics concerning dredges used in Montana—Continued.

Item.	Steam dredges.			Electric dredges.			
	Maggie Gibson.	Conrey No. 1.	Conrey No. 2.	Conrey No. 1.	Conrey No. 2.	Conrey No. 3.	Conrey No. 4.
Well save-all:							
Grade, per cent	None	8	8	8	8	8	8.
Number		1	1	1	1	1	1.
Length, feet		30	30	7½	7½	25⅜	18½.
Width, inches		12	12	18	18	18	18.
Upper flume:							
Grade, per cent	None	5	5	None	None	6	None.
Riffles—							
Material		Wood	Wood			Angles	
Size, inches		1¼ by 2	1¼ by 2			2 by 2½	
Length		21 feet	22 feet			28 feet 10 inches	
Width, inches		42	50			62	
Lower flume:							
Grade, per cent	5	5	5	None	None	6	None.
Riffles—							
Material	Wood	Wood	Wood			Angles	
Size, inches	2 by 4	2 by 4	2 by 4			2 by 2½	
Length, feet	103	120	120			135	
Width, inches	38	52	52			66	
Total gold-saving area, square feet	320	656	692	1,231	1,231	1,261	3,000.

On both the *No. 1* and the *No. 2* dredge the gold won was saved in two sluices, one of which was entirely on the main boat, the other was supported by an auxiliary pontoon and attached to the dredge sluice by spherical socket-joint couplings, which allowed independent movement of the flume, giving flexibility and permitting disposition of the tailings with considerable uniformity. The mooring headline system of anchorage, known locally as the aerial spud, was developed on these dredges and perfected on dredge *No. 3*. It is further described, as is the washing trommel or grizzly, under the discussion of dredge *No. 3*.

When started, the open-connected buckets on dredges *No. 1* and *No. 2* were as large, if not larger, than any worked elsewhere, and these dredges were not only abreast of current practice as to size, but even a step forward. The steam dredges (including the *Maggie Gibson*) worked some 6,000,000 yards of the richest gravel below the mouth of Alder Gulch, averaging about 22 cents a cubic yard. Even though the gravel worked showed such exceptional richness, the operations yielded little if any profit to the owners, when the loss of capital by the abandonment of the dredges was taken into consideration, as the cost of dredges *No. 1* and *No.* 2 amounted to about $225,000. However, they served the useful purpose of giving valuable experience which aided in future successes.

No accurate detailed statement of costs is available for the steam dredges for the whole period of their working, but it has been estimated that they amounted to 16½ cents a cubic yard. For a two-year period of their most economical working—June, 1904, to July, 1906—accurate cost data were kept, and are presented below:

Cost per cubic yard of excavating gravel with dredges 1 and 2.

Gravel dredged, cubic yards	2,412,643
Cost of operation:	
Labor	$0.0270
Salaries	.0053
Material	.0039
Fuel	.0327
Total	.0689
Cost of repairs:	
Labor	.0099
Material	.0240
Shop	.0020
Riffles	.0016
Total	.0375
Miscellaneous expense	.0015
Chain depreciation	.0133
Boston expense, taxes, etc	.0103
Total	.0251
Grand total	.1315

The inefficiency of the steam dredge was so impressed on Prof. Shaler and his associates that prior to the favorable arrangement made with the Madison River Power Co., decision was reached to generate electric power by steam from a central station and to distribute it to the dredges, for it was often a serious matter to coal the boats in cold and stormy weather and in comparatively inaccessible positions. Considerable trouble was also experienced with the boilers, owing to the muddy water from the ponds.

ELECTRIC DREDGE "NO. 3."

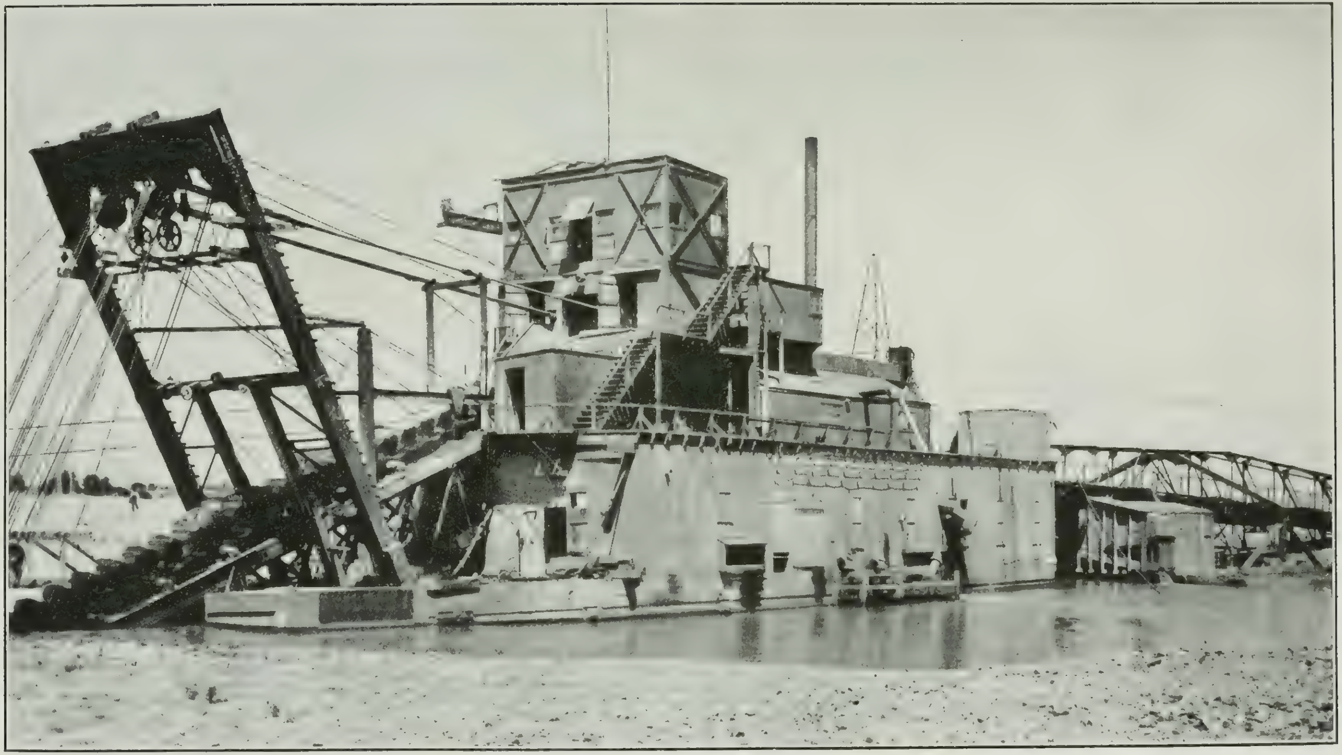
The *No. 3* electric dredge is known as a single-lift sluice dredge. Plates XIII and XV, *A* show side and front views. Plate XIV shows only the most essential outlines; the table on pages 11 to 14 gives various detail data. As shown in the diagram, the hull is 130 by 48 feet by 7 feet 11 inches, and contains 400,000 feet of lumber. A total weight of 1,000 tons of structural material was used in its construction. The total motor rating is 460 horsepower. The dredge started in September, 1906, with 43 open-connected buckets.

Plate XV, *B*, shows a close view of two of the buckets. Each bucket held 13 cubic feet, and weighed 2,910 pounds, each space link weighing 1,250 pounds. The chain was driven by a direct gear-connected motor of 150 horsepower and capable of carrying 100 per cent overload. In September, 1911, the original ladder was lengthened from 100 to 116 feet, and a new close-connected manganese chain of 96 buckets, each holding 9½ cubic feet, was installed, which permitted a dredging depth of 55 feet below water line. Each bucket weighed 2,890 pounds.

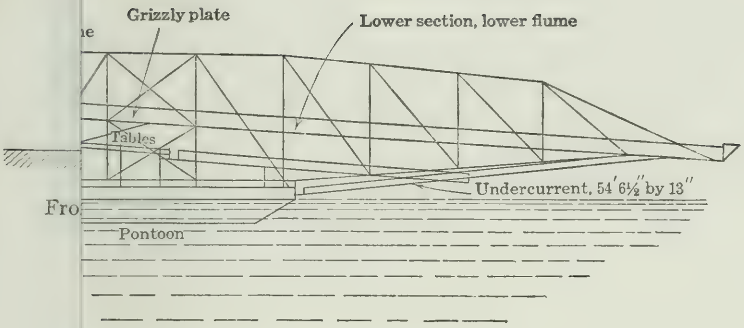
It is interesting to note that the extension of the bucket ladder and the two noses of the "well" pontoons was effected without docking the dredge.

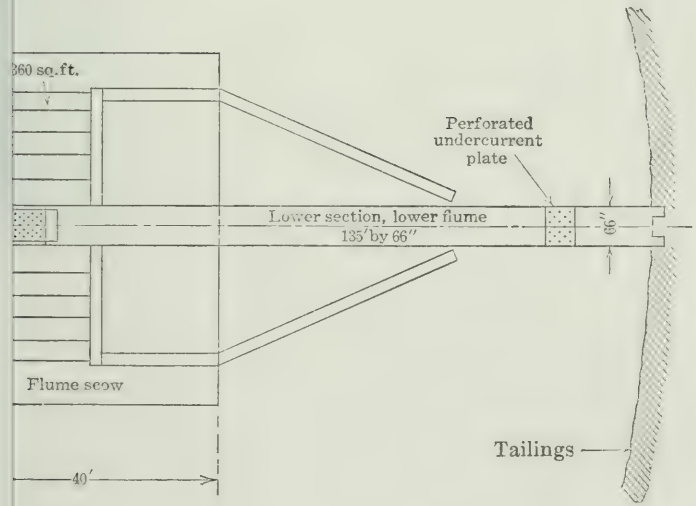
The general arrangement of the washing trommel is shown by Plate XVI, *A*. It is 18 feet long and 61 inches in diameter, with perforations 4½ by 6 inches. The oversize gravel or rock is discharged by chutes on either side of the dredge.

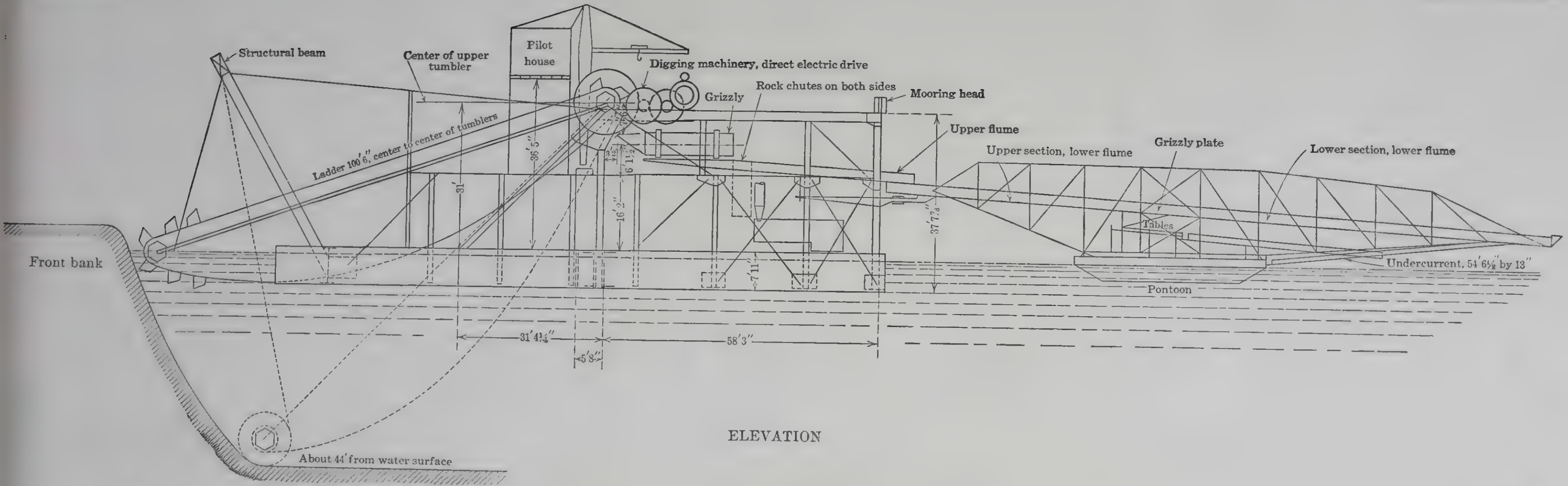
Centrifugal pumps, two of 10-inch, one of 12-inch, and one of 14-inch size, furnish water for the trommel and sluices, about 12,500 gallons a minute being necessary for this type of dredge when digging at full capacity. The pumps require 175 horsepower, and the total motor rating on the dredge is 460 horespower. The flume is 135 feet long by 5½ feet wide, is carried on a separate pontoon, and is built on a 6 per cent grade. With undercurrents and undercurrent tables the total gold-saving area approximates 1,000 square feet.



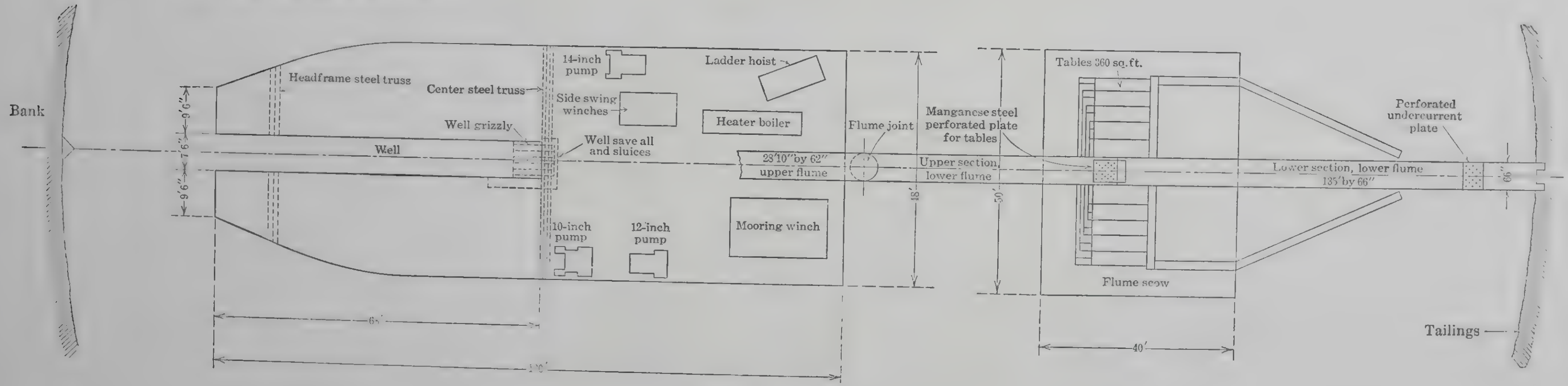
NO. 3 CONREY ELECTRIC SLUICE DREDGE, AS NOW OPERATED; CLOSE-CONNECTED BUCKETS; STARTED 1906.


ıe
Grizzly plate
Lower section, lower flume
Tables
Undercurrent, 54′ 6½″ by 13″
Fro
Pontoon


360 sq.ft.
Perforated undercurrent plate
Lower section, lower flume
135′ by 66″
66″
Flume scow
Tailings
40′

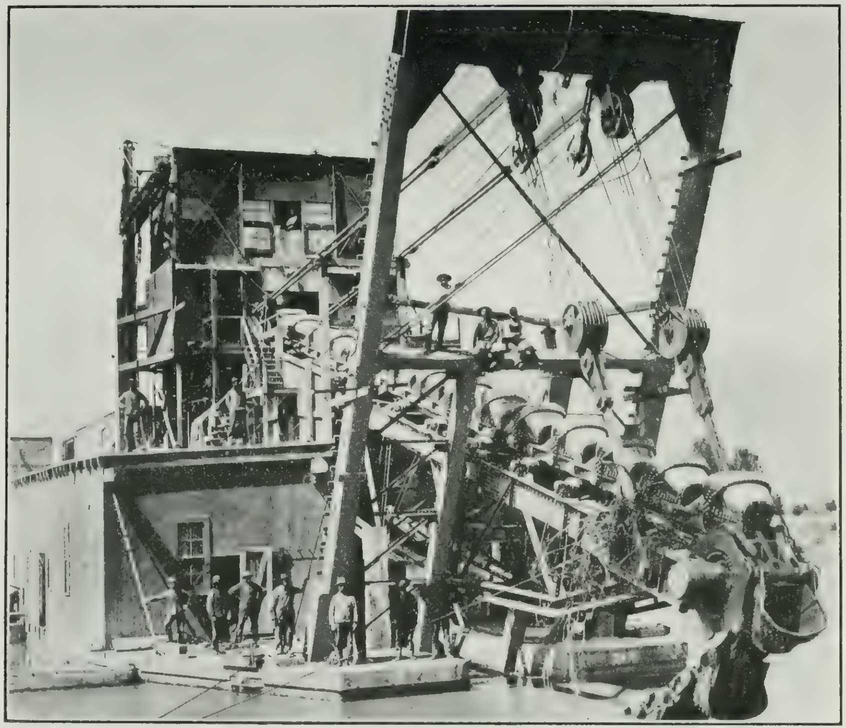

Structural beam
Center of upper tumbler
Pilot house
Digging machinery, direct electric drive
Grizzly
Rock chutes on both sides
Mooring head
Upper flume
Upper section, lower flume
Grizzly plate
Lower section, lower flume
Ladder 100′6″, center to center of tumblers
36′5″
31′
16′2″
6′1½″
3′2″
37′7⅞″
7′11″
Tables
Undercurrent, 54′6½″ by 13″
Pontoon
Front bank
31′4¼″
58′3″
5′8″
About 44′ from water surface

ELEVATION

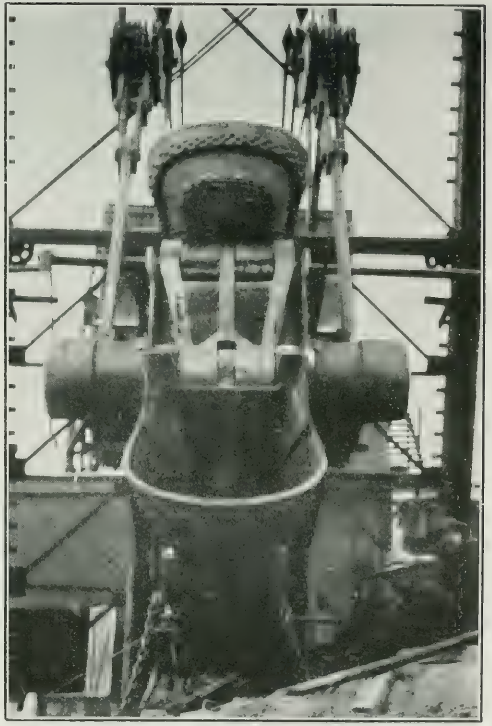


PLAN

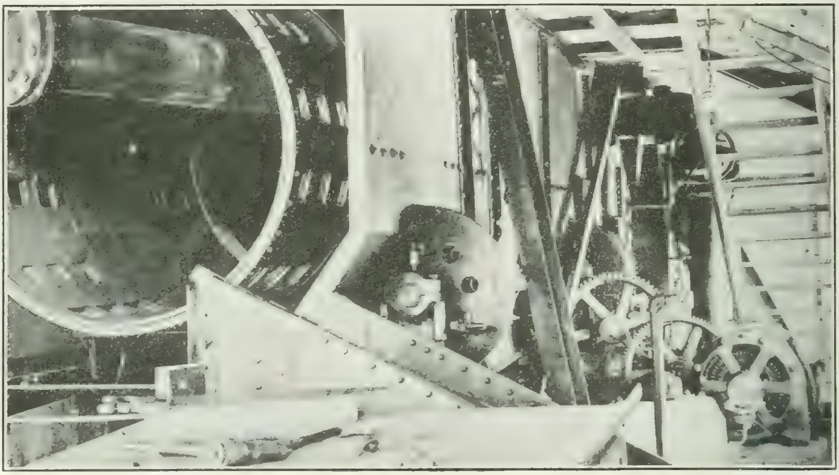
SKETCH OF NO. 3 SLUICE DREDGE.



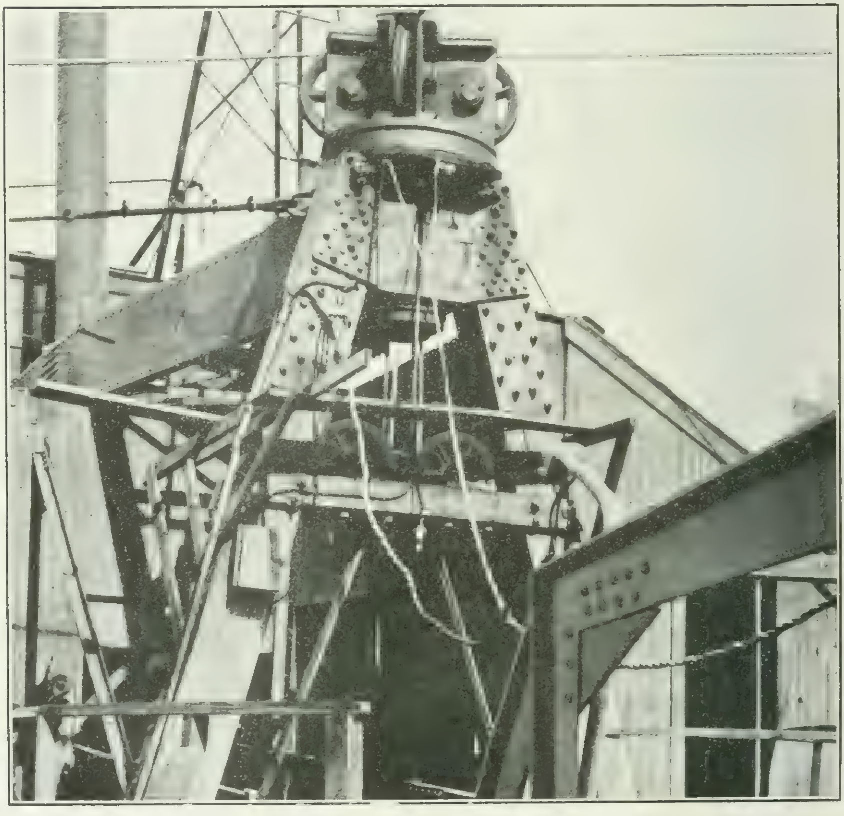
A. NO. 3 DREDGE, OPEN-CONNECTED, 13 CUBIC FOOT BUCKETS, AS OPERATED IN 1906.



B. NO. 3 DREDGE 13 CUBIC FOOT BUCKET RESTING ON LOWER TUMBLER.

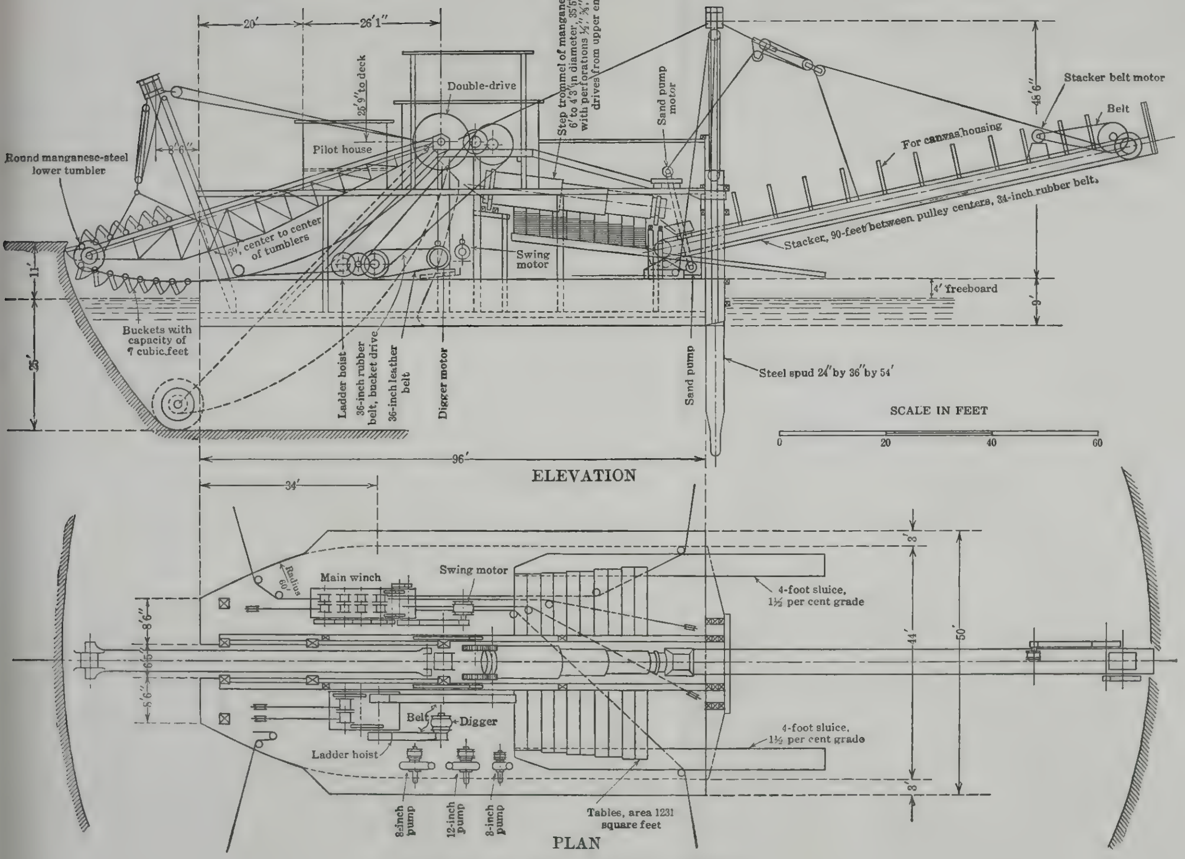


A. WASHING TROMMEL ON NO. 3 DREDGE, CHUTES FOR OVERSIZE GRAVEL ON BOTH SIDES, ONE ONLY SHOWN.



B. AERIAL SPUD ON NO. 3 DREDGE, WITH MOVING LINES.

BUREAU


20′
26′1″
25′9″ to deck
Double-drive
Pilot house
8′6″
Round manganese-steel lower tumbler
69′ center to center of tumblers
Step trommel of manganese-steel, 6′ to 4′3″ in diameter, 35′5″ long, with perforations ½″, ⅜″, and ¼″, drives from upper end.
Sand pump motor
Stacker belt motor
Belt
For canvas housing
48′6″
Stacker, 90-feet between pulley centers, 34-inch rubber belt.
Swing motor
4′ freeboard
9′
11′
25′
Buckets with capacity of 7 cubic feet
Ladder hoist
36-inch rubber belt, bucket drive
36-inch leather belt
Digger motor
Sand pump
Steel spud 24″ by 36″ by 54′
SCALE IN FEET
0
20
40
60
96′
ELEVATION
34′
Radius 60′
Main winch
Swing motor
4-foot sluice, 1½ per cent grade
8′6″
6′5″
8′6″
3′
44′
50′
3′
Belt
Digger
Ladder hoist
4-foot sluice, 1½ per cent grade
8-inch pump
12-inch pump
8-inch pump
Tables, area 1231 square feet
PLAN

SECTIONS OF NO. 1 ELECTRIC DREDGE.

The aerial spud is shown in Plate XVI, *B*, and in Plate XIV is indicated at the point designated "mooring head." It consists of a spindle supported by a ball-bearing casting fastened to the top of a wooden frame built firmly on the back of the boat. Mooring lines 500 to 700 feet long, radiating from winches over the sheaves fastened to the spindle head, are anchored to the shore. When the boat is moved two bow lines are wound up and the stern lines loosened. The lines are then clamped and the boat is firmly held in a fixed position. The forward end of the boat with the bucket chain swings sidewise in an arc about the mooring head as a center, and is drawn across the pond by the side-line winches. The flume swings about the same center through a reverse arc.

The dredge is operated by 10 men—three on two shifts and four, including the dredge master, on a third shift. The superintendent, Julius Baier, started to design this dredge in 1904, but it was not put into operation until more than a year after his death. It is without doubt the largest and most perfectly equipped dredge of its kind known in the gold-dredging industry. The method of bracing the hull and the flexibility of the mooring-line system have allowed this dredge to work nine years without injury to the hull. Its relative efficiency is discussed subsequently.

ELECTRIC STACKER DREDGES "NO. 1" AND "NO. 2."

The electric stacker dredges *No. 1* and *No. 2* were built by the Marion Steam Shovel Co. These dredges are constructed on the lines of California practice, but have many details initiated at Ruby. They were built for varying classes or work; the table on pages 11 to 14 records their main features. The 7½-foot close-connected bucket chains on electric stacker dredges *No. 1* and *No. 2* are interchangeable, each having a 32¾-inch pitch, and are made of manganese steel. These two dredges are of similar appearance. Plate VI, *A*, shows *No. 2* at work. Plate XVII gives the actual dimensions for *No. 1* alone but is applicable to *No. 2* in principle, as both dredges are constructed on identical lines. The different dimensions are given in the table on pages 11 to 14.

The table shows that the length of the bucket ladder of the *No. 1* dredge is only 70 feet, whereas the stacker is 90 feet, which, in connection with its short hull, permits it to work up Alder Gulch in narrow and difficult places and with high banks in front of it and allows it to do some hydraulicking, as is shown by Plate VIII (p. 8). The campaign of this dredge has been most satisfactory in consideration of the difficulties of winter and in some places adverse bedrock conditions.

Plate XXIX, *B*, shows the *No. 2* dredge as a wreck. Its sinking was due to weakness in the hull when subjected to great strain. It was, however, docked, repaired, and strengthened and put in successful operation again in a short time, and is now capable of working economically gravel to a depth of 35 feet.

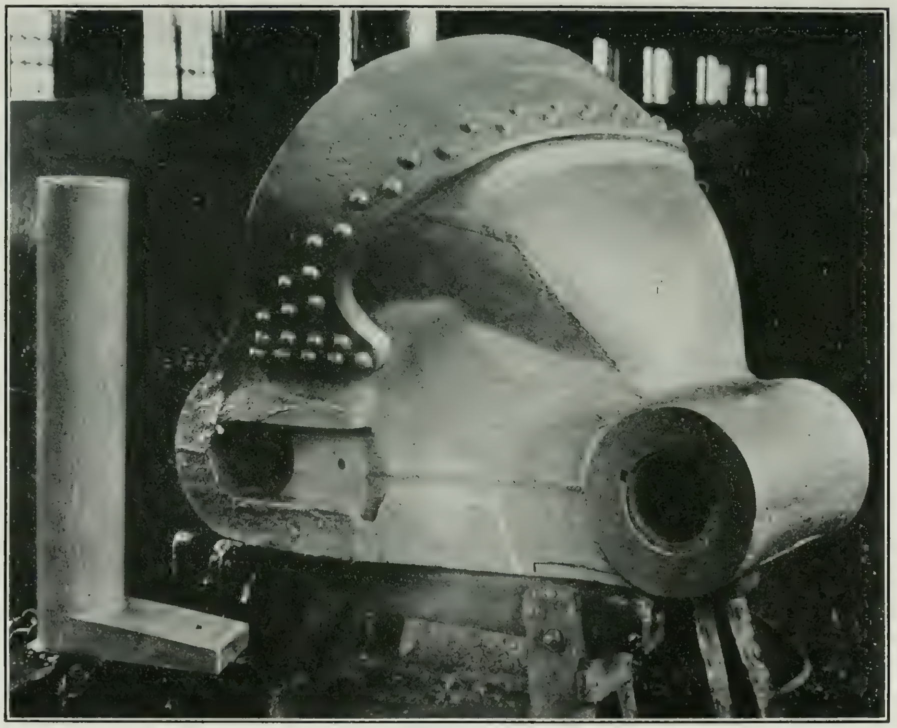
"NO. 4" ELECTRIC DREDGE.

The *No. 4* dredge was designed to work economically large areas of ground with small gold contents to a depth of 55 feet below water level. As in places exacting dredging conditions had to be met, effort was put forth to make the dredge as strong as any gold dredge before built. When it began work in 1911 the bucket line, washing trommel, and digging motor, though as powerful and heavy as had been used before, were inadequate for their work; but all have been gradually renewed and greatly strengthened, and are now the heaviest and strongest in use. The record month's performance (May, 1915) of digging 411,000 cubic yards with 82 per cent running time, with a depth of 54 feet and an operating cost of 2.66 cents per yard, justifies a more detailed description. Plate XX gives a clear and complete outline of all the fundamental parts of this dredge and their relationship and with figures for dimensions. Some details that are similar to details shown in Plate XVII are omitted in Plate XX. The drive of the washing screen shown at the top of the screen was afterwards changed to the bottom, where it worked far more efficiently. Details of the trommel and drive are shown on Plate XXI.

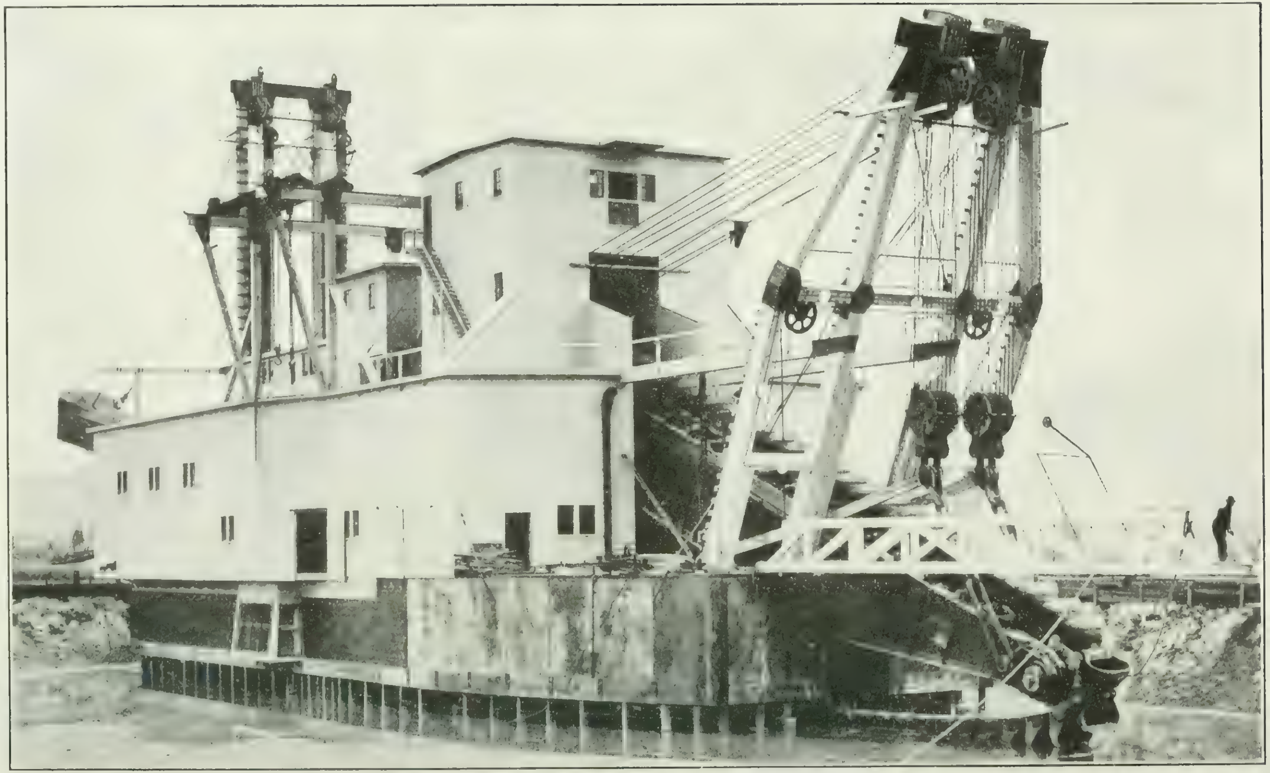
The *No. 4* dredge, as also the *No. 1* and the *No. 2*, is operated on the spud system. The spud is the pivot around which the side lines and winches make the dredge move across the pond on an arc, and as the digging ladder is lowered or raised, the excavation is made in the form of curved slopes or terraces. The dredge is advanced by two spuds, one for the stepping forward at the end of a full swing across the pond. All the digging machinery and winches are controlled by one man in the pilot house.

Plate XIX shows the *No. 4* dredge in the construction pond just before its flotation. The steel sheathing for protection against ice is shown.

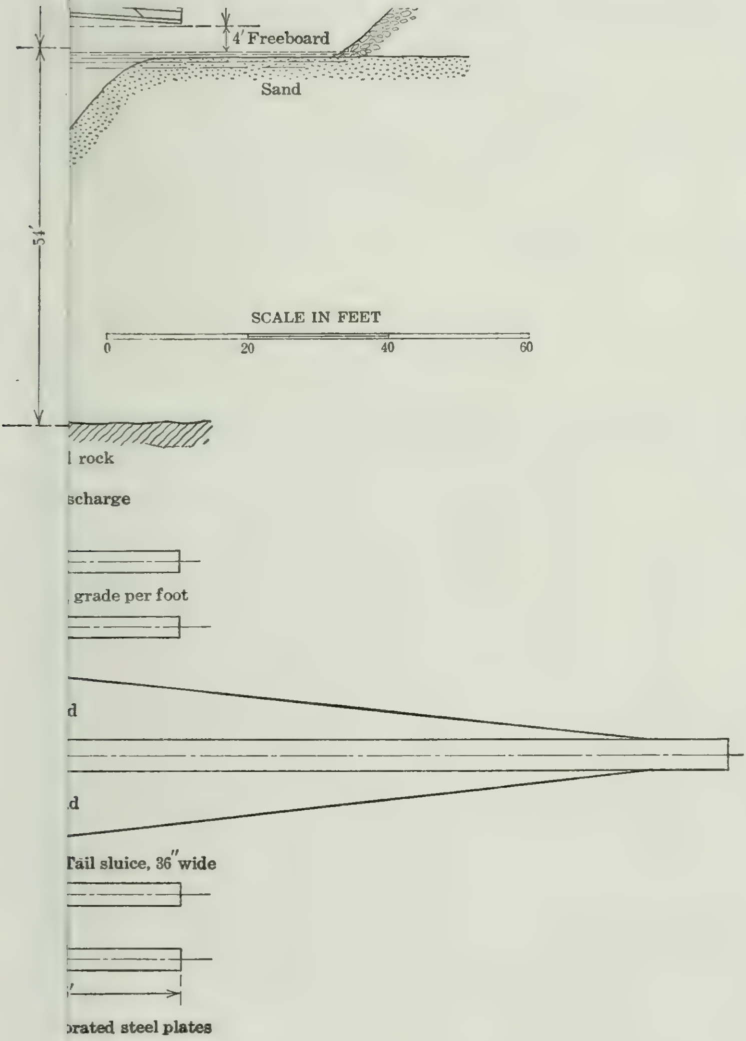
Plate XVIII shows the bucket now in use with circular manganese bushings. It holds 16 cubic feet and weighs 5,200 pounds. Plate XXII shows the revolving washing screen, which is 50 feet long and 8 feet 9 inches in diameter. It weighs 110 tons. The special cross-truss braces between the ribs are shown. This is probably the heaviest trommel in use in gold dredging. One of the spuds, 80 feet long and weighing 44 tons each, is shown on railway trucks in Plate XXVII, *A*.

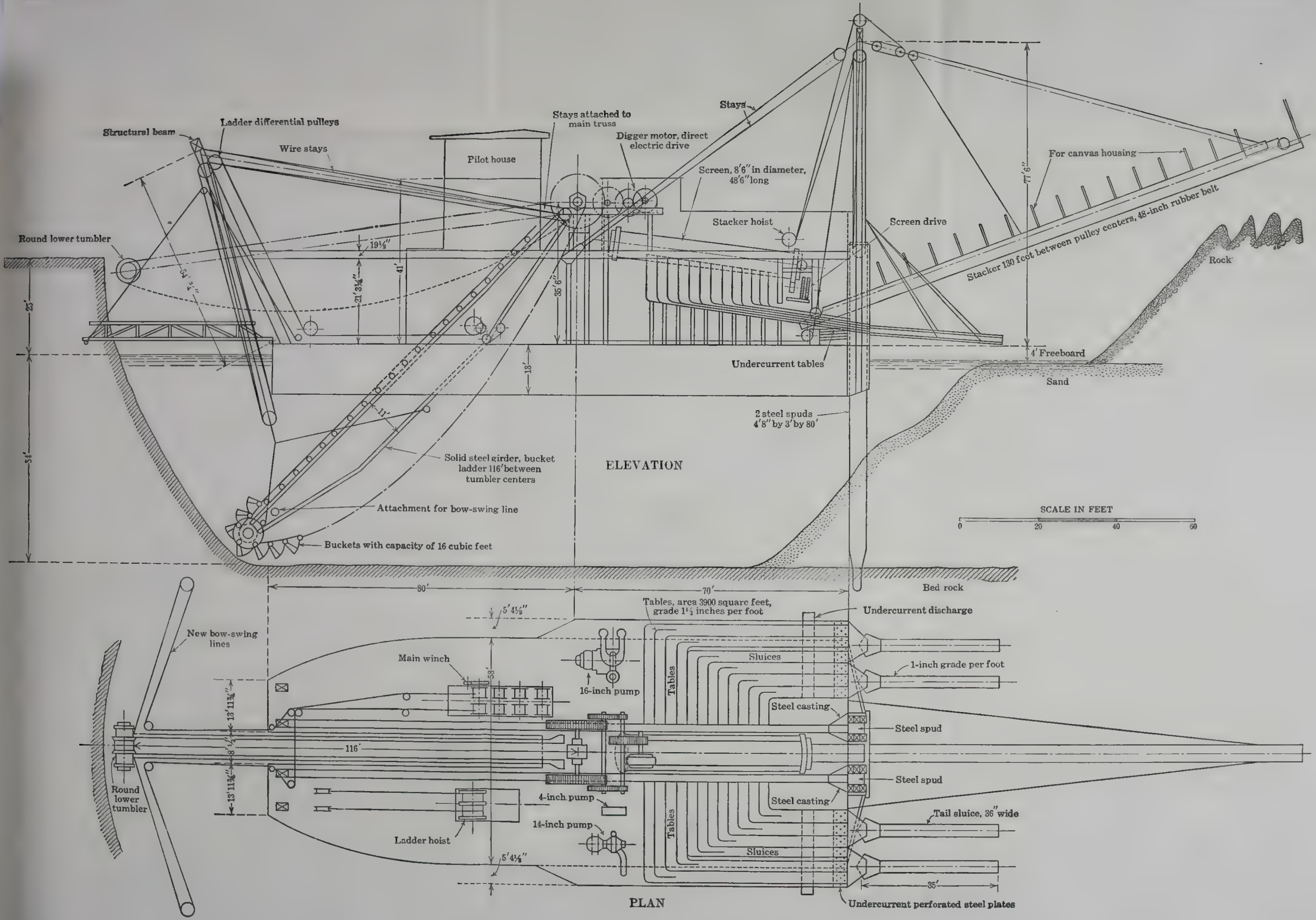


NO. 4 DREDGE, 16-FOOT MANGANESE STEEL BUCKET.

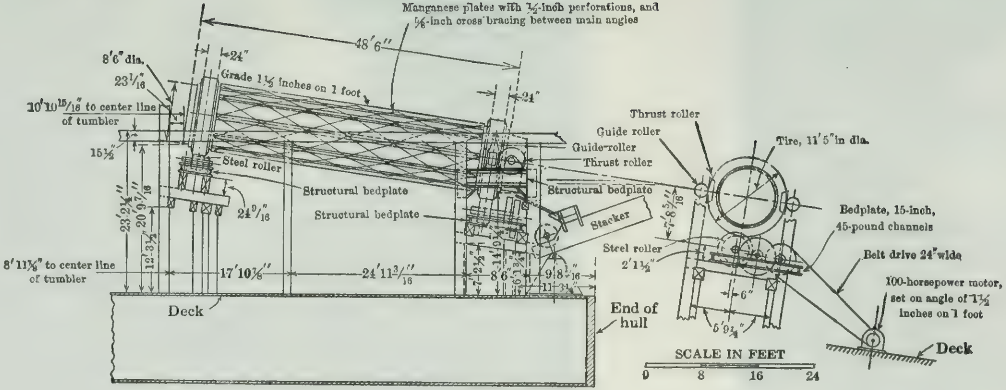


NO. 4 DREDGE IN CONSTRUCTION POND ABOUT TO BE FLOATED, 1911

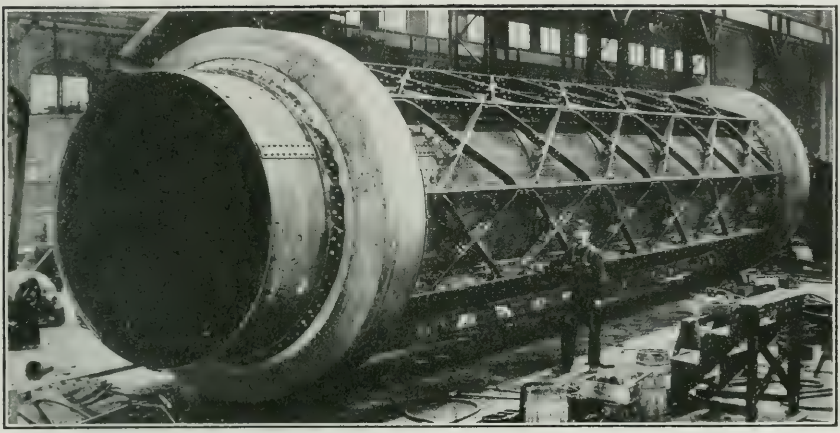

4' Freeboard
Sand
54'
SCALE IN FEET
0
20
40
60
l rock
scharge
, grade per foot
d
d
Tail sluice, 36" wide
'
orated steel plates



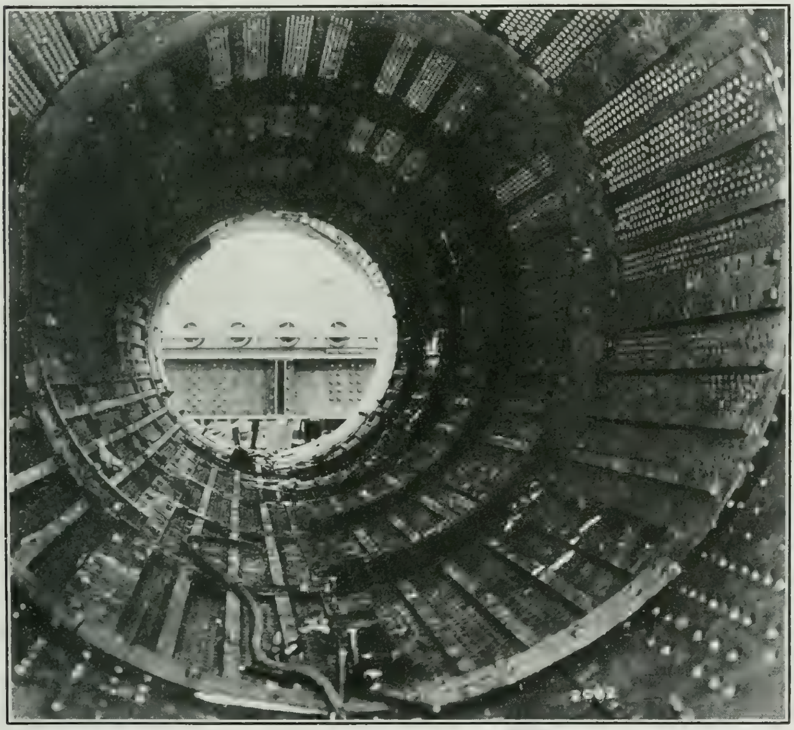
SECTIONS OF NO. 4 DREDGE (MAIN BUT INCOMPLETE DETAILS).



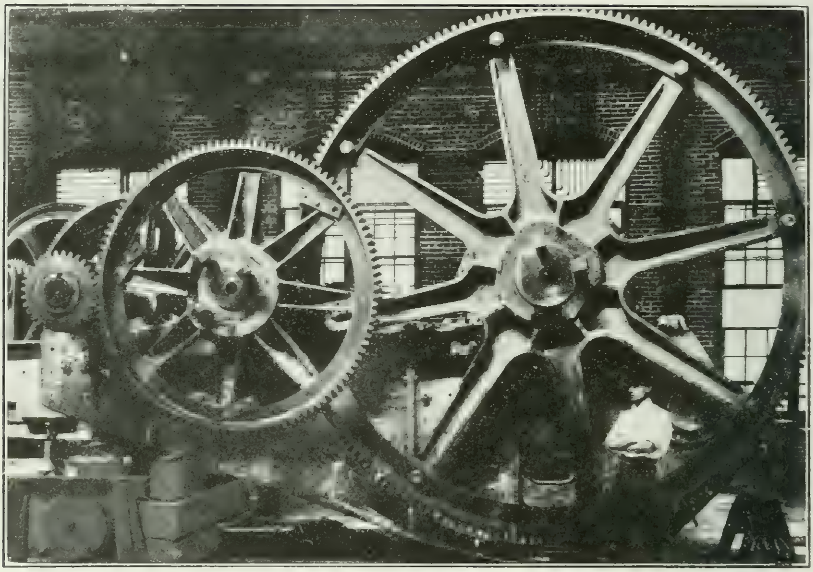
SECTIONS OF WASHING SCREEN, NO. 4 DREDGE.



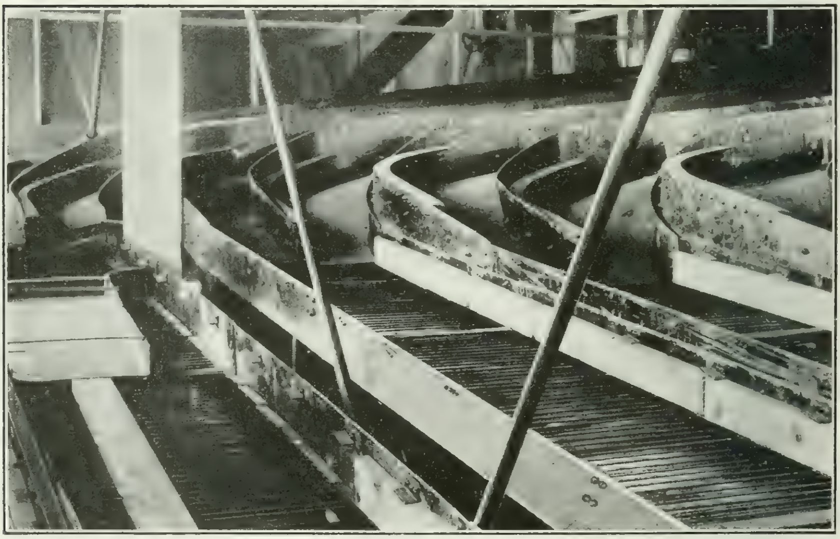
A. WASHING SCREEN FOR NO. 4 DREDGE, 50 FEET LONG, 8 FEET 9 INCHES IN DIAMETER, WEIGHT 110 TONS.



B. NO. 4 DREDGE, INTERIOR OF WASHING SCREEN, SHOWING MANGANESE PLATES.



A. DIGGING MOTOR AND GEARING, NO. 4 DREDGE.



B. GOLD-SAVING TABLES AND SLUICES, NO. 4 DREDGE.

The 550-horsepower digging motor and the gear that couples it direct to the bucket-chain drive are shown in Plate XXIII, *A*. This motor is the largest in use in gold-dredging practice. The table on pages 11 to 14 shows that the total motor rating of the boat is 1,285 horsepower and that the increase in the weights and dimensions of the various parts of the different dredges has followed the horsepower used.

The steel gold-saving tables and sluices on the *No. 4* dredge through which 12,000 gallons of water per minute is passed are shown in Plate XXIII, *B*. The water is raised by one 16-inch low-pressure centrifugal pump and one 14-inch high-pressure centrifugal pump. The gold-saving appliances have an area of about 3,000 square feet. Two 10-ton traveling cranes are placed over the main drive for convenience in repairs and adjustments.

The hull is 150 feet long with a deck bearing surface 68 feet wide. It is 13 feet deep. The machinery for the dredge weighed 2,280,000 pounds, and 660,000 feet of lumber was used in the hull, making a total weight of about 2,000 tons for the completed dredge. The digging ladder, 116 feet long, is equipped with 80 close-connected 16-foot manganese buckets with a weight of 5,200 pounds; the earlier carbon-steel buckets weighed only 4,468 pounds. The upper tumbler shaft is 25 inches in diameter and weighs 10 tons, the tumbler and shaft complete weighing 27½ tons.

SOURCE OF ELECTRIC POWER FOR CONREY DREDGES.

Power for all the electric dredges is obtained from the Madison River Power Plant, 26 miles distant, and is transmitted to the Conrey substation at 46,200 volts, where it is stepped down to 2,200 volts and sent direct to the dredges over independent power lines. Dredges *No. 1*, *No. 2*, and *No. 3* have 2,200 volts, and 400-volt motors and transformers are placed on these boats for further reduction of voltage of part of the power. Dredge *No. 4* uses 2,200 volts throughout, and only one transformer for electric lights is required. At the substation there are three banks of transformers, each capable of 2,815 horsepower with a maximum reduction of 80,000 to 2,200 volts. Two banks are in constant use, the third being held in reserve. Plate XXIV, *A*, shows the switchboard at the transformer station. In connection with this station and the different power lines to the various dredges and to the machine shop over $50,000 has been spent.

IMPORTANCE OF WELL-EQUIPPED MACHINE SHOP.

It has been necessary for the Conrey company, in view of all its extensive dredge construction and repair work, especially since the dredges have become more powerful, to have a very complete machine shop and equipment and an adequate force of skilled mechanics. In this machine shop parts such as tumblers of 24 tons weight have been handled and repaired. An upper tumbler of *No. 1* or *No. 2* dredges in one of the planers is shown in Plate XXIV, *B*. Machinery of dredges that have sunk has been rehabilitated; a steel truss made from angle irons of a discarded screen of *No. 4* dredge was put together to cure the warping and settling of the hull of *No. 2* dredge at the well. The relipping and bushing of bucket chains is an ever-recurring work.

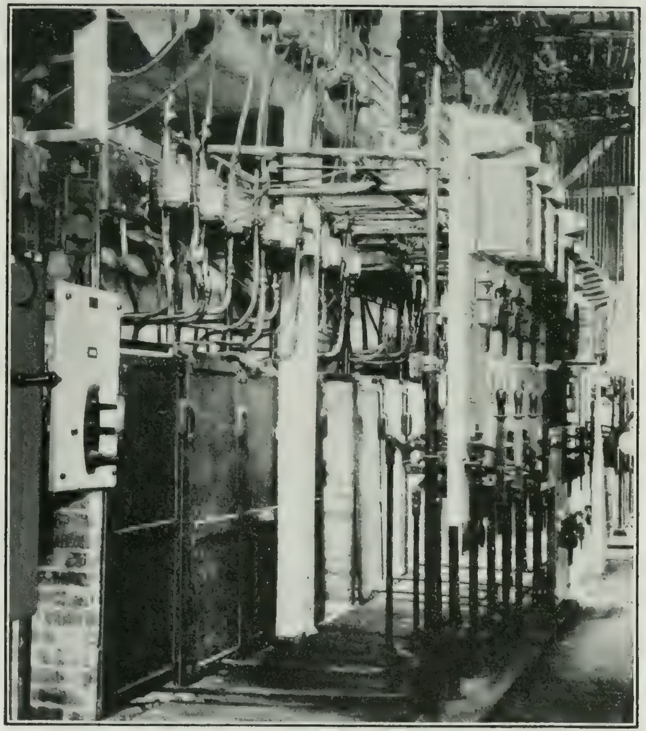
During the time of the erection of new dredges the machine shop was called on for assistance in many ways. To deal with current work and emergency requirements a force of skilled mechanics was kept employed. In the operating costs it will be found that approximately 30 per cent is in connection with repair work. The Conrey company's machine-shop equipment has cost in the neighborhood of $50,000. It has also been found necessary to keep on hand some $60,000 to $80,000 worth of spare parts and materials.

MEN EMPLOYED ON DREDGES AND OPERATION COSTS.

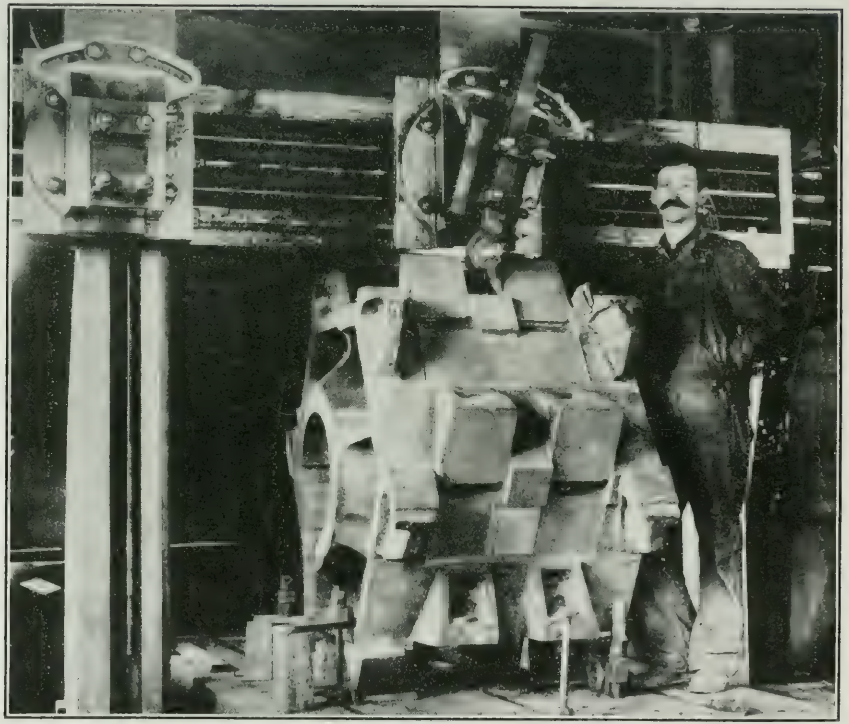
The dredges are worked on eight-hour shifts. The total force required for normal working of all the dredges is shown in the tabulation following, as are the cost of the dredges and other statistics:

Number of men employed for normal working of all dredges of Conrey company, and cost of equipment.

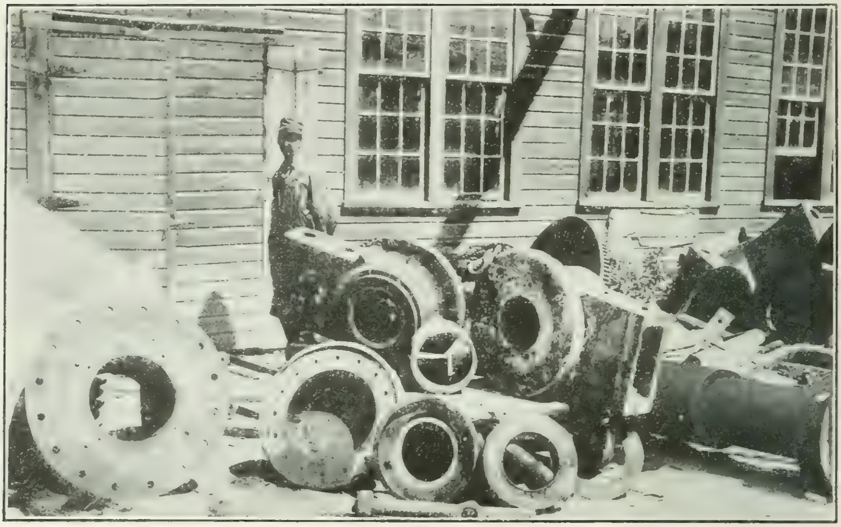
Item.	Men.	Cost of equipment.
Operation of steam dredges abandoned:		
Maggie Gibson	13	....
No. 1	15	$225,000
No. 2	15	
Operation of electric dredges in use:		
No. 1	8	108,000
No. 2	8	128,000
No. 3	10	198,000
No. 4	10	296,000
Office and dwellings	4	15,000
Transformer station and pole line	2	50,000
Machine shop	8	50,000
Clean-up crew	3	....
Labor	22	....
Miscellaneous	10	....
Total	85	1,070,000



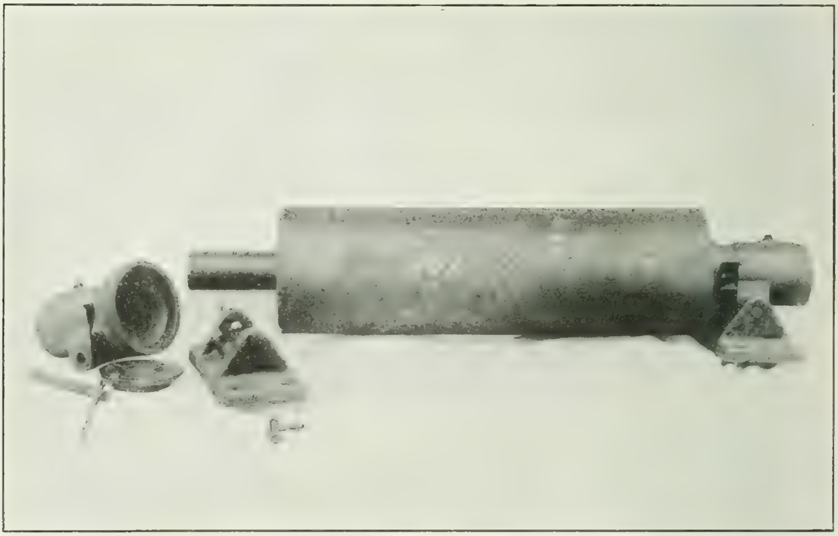
A. SWITCHBOARD TRANSFORMER STATION, RUBY, MONT.



B. TUMBLER IN PLANER, NO. 1 OR NO. 2 ELECTRIC DREDGE.



A. LOWER TUMBLERS SHOWING WATER-TIGHT BEARINGS.



B. LADDER ROLLER SHOWING WATER-TIGHT BEARINGS.

COMPARATIVELY FAVORABLE DREDGING CONDITIONS IN CALIFORNIA.

In the dredging districts of California two or three large machine-shop equipments do the work for a great number of dredges, so that the cost is less than is possible at an isolated district like Ruby. The improvements in mechanical detail have also been greatly stimulated in California by numerous dredging men being thrown together and exchanging ideas and vying with each other for improvements.

IMPROVEMENTS DEVELOPED IN RUBY DISTRICT.

Nevertheless, in spite of the isolation of the work at Ruby, many improvements in the details of dredge construction have originated or been advanced there. Some of these are as follows:

The mooring-head or aerial-spud system previously explained was there developed.

The Ruby dredges were among the first to try out large buckets. The first 10-foot buckets were tried there on sluice dredge *No. 2*, and these were followed by 13-foot buckets on the *No. 3* dredge, and afterwards by 16-foot buckets on the *No. 4* dredge. The one-piece manganese bucket—that is, one having the hood and base cast together—had there early exhaustive tests. Circular manganese bushings for buckets' eyes were first tried at Conrey and have proven satisfactory. The water-tight bearings for lower tumbler shafts (Pl. XXV, *A*) and for ladder rollers (Pl. XXV, *B*) as developed at Conrey have proven most successful, as have the self-aligning bearings for the upper tumbler shaft.

Manganese baffle plates for the revolving screen (see Pl. XXII, *B*) were first adopted at Conrey. These were made by the American Manganese Steel Co. and have since come into general use. As compared to seven months' wear formerly obtained with the "carbon-screen" plates, the manganese plates give nearly two years' wear.

The Ruby dredges were among the first to use 2,200-volt motors. The control arrangement on the *No. 4* dredge is what is known as a water rheostat, and was there first successfully applied to gold dredging.

Previous to the construction of the *No. 3* dredge the bucket drive on Conrey dredges was by means of sprocket chains, and on California dredges by belts. With the *No. 3* and the *No. 4* dredges the bucket drive has been by means of direct gear-connected motors placed on the upper deck. Undue shocks and overloads on a motor are arranged for by a slipping friction clutch and by a current breaker placed on the digging motor power line. This system of bucket drive has proven satisfactory at Ruby and has been adopted for a few large dredges in other fields.

GOLD RECOVERY IN RUBY DISTRICT.

In regard to gold recovery, the property as a whole was never thoroughly or systematically prospected by drilling, but drill holes were sunk over considerable areas. The recovery made by the dredges of the gold contained in these areas has at times closely accorded with the estimates and at other times been disappointing. As a whole, the company is not in a position to make any accurate statement as to the percentage of recovery by returns or bore holes, but there have not been any great discrepancies. The subject of keystone drilling will not be here taken up, as its records and principles have been the subject of much literature.

The amalgam returns from the clean-ups of the dredges show the percentage of gold recovery from the different electric dredges up to July 30, 1915, to be as follows:

Gold recovery from different electric dredges of Conrey company up to July 30, 1915.

Dredge *No. 1:*	Per ct., 87 months.
All 20 tables	92.76
Tail sluices	3.02
Well	4.22
	100.00

Dredge *No. 2:*	Per ct., 86 months.
All 20 tables	93.34
Tail sluices	3.83
Well	2.83
	100.00

Dredge *No. 3:*	Per ct., 106½ months.
Upper flume	55.55
Lower flume, first section	26.81
Lower flume, second section	7.14
Lower flume, below undercurrent	.53
Undercurrent	1.38
Well	5.05
Tables	2.93
Tail sluices	.28
Miscellaneous	.33
	100.00

Dredge *No. 4:*	Per ct., 49½ months.
First 16 tables	85.32
Last 8 tables	2.60
Tail sluices	8.94
Undercurrent	.55
Well	2.59
	100.00

CHARACTER OF GOLD RECOVERED.

The fineness of the bullion from the different dredges varies from 0.822, for the *No. 1* dredge working farthest up the gulch, to 0.873 for the *No. 4* dredge working farthest below the mouth of the gulch.

The striking feature of the gold recoveries, especially in the stacker table dredges, is the large percentage recovered near the head of each table and sluice and nearest to the upper section of each washing trommel.

A feature of the returns from the *No. 3* dredge is the 2.93 per cent recovery from the undercurrent tables, which after their installation made no difference to the returns of the sluice area below them. They have caught since their installation in December, 1908, about $35,000 worth of gold, and this recovery is a distinct proof of the danger of loss of fine gold in the sluice system.

The undercurrents on the *No. 4* dredge have been constructed with care and completeness but a recovery of only 0.55 per cent for 49½ months' working has been made. This recovery has more than met operating expenses of the undercurrent upkeep and given foundation for the belief that there is little or no commercial loss of gold taking place on this dredge.

The percentage of 8.94 per cent recovered from the tail sluices of the *No. 4* dredge compared to 3.02 per cent and 3.83 per cent from *No. 1* and *No. 2* dredges, in conjunction with the low undercurrent returns, speaks well for the efficiency of these sluices, which are shown in Plate XXIII, *B*.

The recovery from the well save-alls varies from 2.59 per cent of the total clean-up on the *No. 4* dredge to 5.05 per cent on the *No. 3* dredge. The arrangement of a well save-all on one of the earlier dredges is shown in Plate XXVI, *A*. The recovery made by the save-alls on the different dredges is indicative of the losses that can be sustained by material from spills of the buckets caused by stickiness of material, overfilling, and noncleaning of buckets. The different gold-saving devices in the well save-alls are somewhat similar, but in some dredges it is easier to guard against a spill than in others.

On the *No. 4* dredge it is possible there is less spill than on any of the other dredges and consequently less percentage of gold caught.

Some of the tailings and ground that had been worked by the steam dredges was reworked by the *No. 2* stacker electrical dredge and the *No. 3* sluice dredge, with varying returns from 0.5 cent to 3.73 cents per yard. This variation would indicate defective gold-saving devices on the earlier dredges but also indicates another weakness in the sluice system—its liability to leave ridges of unworked ground.

The gold recovered from the Conrey and the Poor Farm ground is distinctly coarse, but not many nuggets have been found. Even in the *No. 3* dredge the largest nugget so far recovered was worth only $17. There are few nuggets found that are worth over $5. On the whole, the Conrey company's gold-saving problem is not as serious as in most districts of California.

COMPARATIVE EFFICIENCY OF DIFFERENT TYPES OF DREDGES.

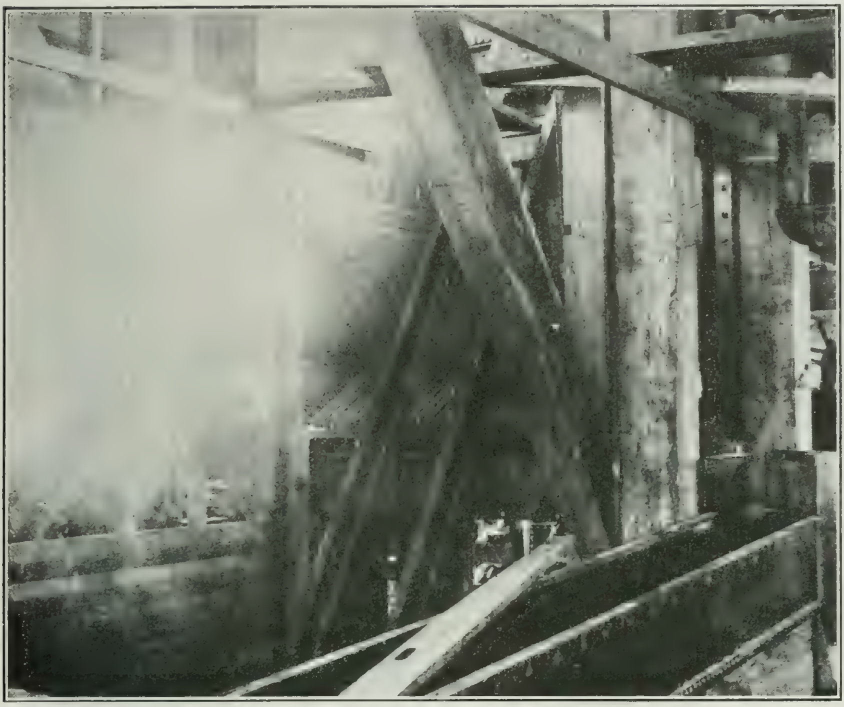
The Conrey company's technical operations are unique in that they started in the earliest days of gold-dredging work in this country and on the company's property the steam dredge has been tried against the electric dredge, and the electric sluice dredge has been tried against the stacker type.

In the company's efforts for advancement, extending over 16 years, the development of the gold-dredging industry has been mirrored by their construction work, described in the foregoing pages, and visualized by Plates XXVI, *B*, and XXVII, *B*, which show the progressive sizes of the buckets and bucket pins used in the Ruby district on the different dredges.

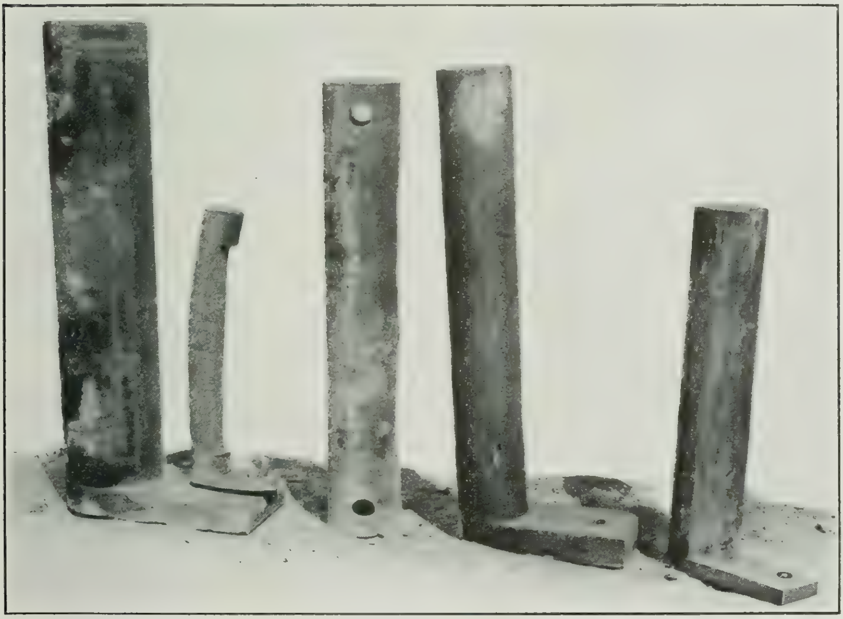
The high operating costs and disadvantages in connection with the steam dredge have been shown and need not be further emphasized.

The electric sluice and stacker types of dredges as developed at Ruby to their maximum size and greatest efficiency can be here well compared. The sluice type can show a few advantages, for example, in dealing with coarse, nuggety gold that will not pass the perforations of the ordinary washing screens on stacker dredges. There has, however, been little or none of such gold at Ruby. With the mooring-line system or aerial spud there are less serious strains on the hull, illustrated by the fact that the hull of the *No. 3* dredge has been subject to no repairs for excessive strain after working nine years, and is in perfect condition. This system of dredging has also the advantage of leaving the country dredged in more presentable shape and facilitates reclamation for agricultural purposes. It is interesting to note that ground early dredged is now covered with wild sweet clover, useful as a feed.

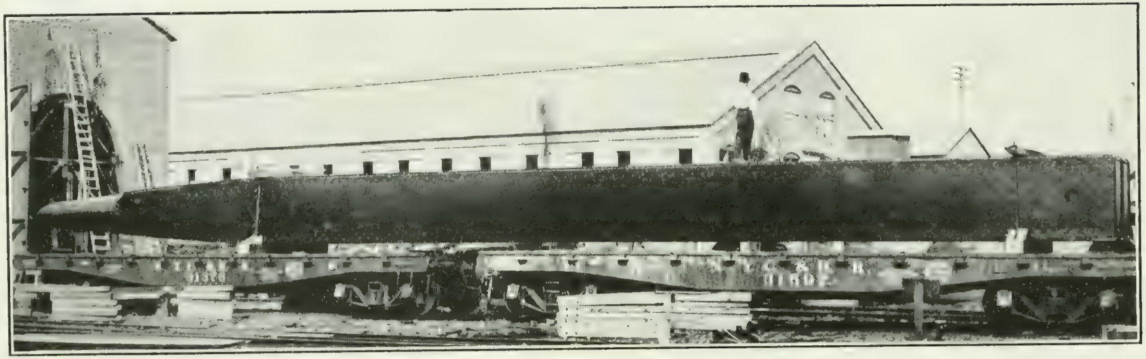
On the other hand, the sluice dredge is inferior as a saver of fine particles of gold, as the redredging of a quantity of sluice-dredged tailings by stacker boats has conclusively demonstrated. The sluice-dredging system requires also the reworking of a large quantity of tailings to reach the virgin ground covered by the first tailings. It is particularly ineffective in working gravel of great depth downstream. It also is not adapted to working through extreme cold weather, as a much larger pond must be kept free of ice. However, if all the disadvantages under which *No. 3* has worked are considered, the results obtained are a proof of the excellence of its construction and the skill of its management.



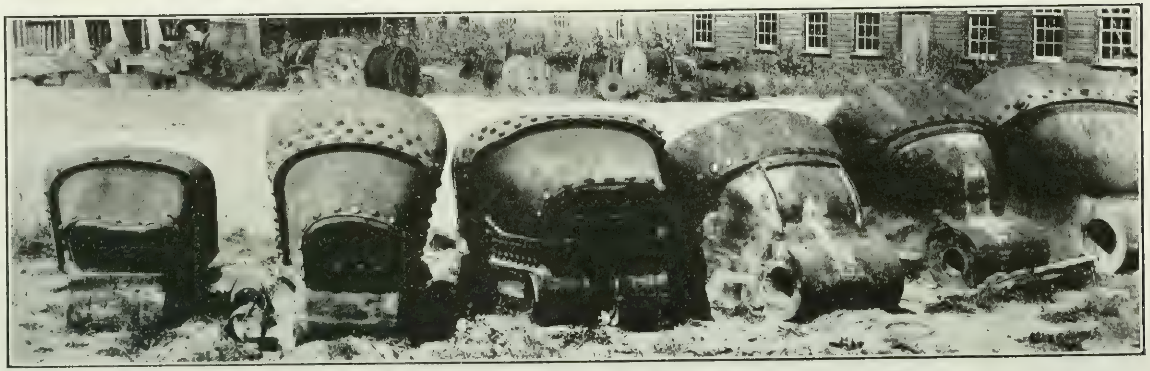
A. WELL SAVE-ALL AND SLUICE.



B. BUCKET PINS FROM DIFFERENT DREDGES, SHOWING DEVELOPMENT. LEFT TO RIGHT, CONREY NO. 3, MAGGIE GIBSON, LOCK PIN NO. 3, LUG PIN NO 3, NO. 1 AND NO. 2 ELECTRIC DREDGES.



A. STEEL SPUD FOR NO. 4 DREDGE, 80 FEET LONG, WEIGHT 44 TONS.



B. DEVELOPMENT OF BUCKETS. LEFT TO RIGHT: MAGGIE GIBSON OR NO. 1 STEAM, 5 CUBIC FEET; NO. 2 STEAM, 10 CUBIC FEET; NO. 3 ELECTRIC, 13 CUBIC FEET; NO. 3 ELECTRIC, 9½ CUBIC FEET; NOS. 1 AND 2 ELECTRIC, 7½ CUBIC FEET; NO. 4 ELECTRIC, 16 CUBIC FEET.

DATA ON COST OF DREDGING IN MONTANA.

ACCOUNTING METHODS USED BY CONREY COMPANY.

The methods of accounting and the details of cost statistics, as well as lost time kept by the Conrey company, are illustrated by the three blank forms following. They show the balance sheet, profit-and-loss account, and statement of operation of dredges used by the company. A statement of time lost from January 1 to July 31, 1915, also follows.

Balance sheet used by Conrey Placer Mining Co.

Assets.			Increase.	Decrease.
Cash mines bank				
Cash mines office				
Cash with treasurer				
Bullion in hand				
Accounts receivable (list)				
Stock—warehouse (list)				
Stock—fuel				
Prepaid accounts				
Dredge No. 1				
Dredge No. 2				
Dredge No. 3				
Dredge No. 4				
Machine shop and tools				
Minor personal property				
Lands, buildings, etc				
Substation and pole line				
Deferred charges (list)				

Liabilities.			Increase.	Decrease.
Accounts payable (list)				
Notes payable				
Accounts accruing				
Capital stock				
Reserve for upkeep of chain				
Surplus account				

.... *Bookkeeper.* .... *Manager.*

Profit-and-loss report used by Conrey Placer Mining Co.

Profit-and-Loss Report for Month of ....

Cubic yards dredged.	Month of............		Year to date...months.	
Dredge No. 1				
Dredge No. 2				
Dredge No. 3				
Dredge No. 4				
Total				
Operating costs.		Average per yard.	Months.	Average per yard.
Dredge No. 1				
Dredge No. 2				
Dredge No. 3				
Dredge No. 4				
Total				
Indirect expenses.				
Salaries, mines				
Salaries, Boston				
Expenses, Boston				
Interest				
Insurance				
Taxes				
Telephones				
Office expense				
Building repairs				
Living quarters				
Miscellaneous expense				
Stable expense				
Maintenance substation and pole line				
Roads, ditches, and fences				
Prospect drilling				
Ranch expense				
Total indirect expenses				
Total operating costs				
Total expenses				
Balance net earnings to surplus account				
Net bullion and earnings.				
Dredge No. 1				
Dredge No. 2				
Dredge No. 3				
Dredge No. 4				
Net bullion, total				
Ranch returns				
Rents				
Lights				
Scrap				
Interest receipts				
Shop receipts				
Miscellaneous receipts				

.... *Bookkeeper.* .... *Manager*

Form of operating report used by Conrey Placer Mining Co.

Operating Report for Month of .... Dredge No. ....

Time.	Month of	Year to date..........................	months.
Running hours..........................	per cent.	Hours..........................	per cent.
Lost hours..........................	per cent.	Hours..........................	per cent.
Total hours..........................	100 per cent.	Hours..........................	100 per cent.

Excavation.		Months.
Cubic yards dredged..........................virgin..		
Cubic yards dredged..........................tailings..		
Cubic yards dredged..........................gross..		
Average per running hour..........................		
Average per bucket..........................		
Buckets per minute..........................		
Average kilowatt-hours per yard..........................		
Acres dredged..........................		
Average depth to bedrock..........................		

Production.		Average per yard.	Months.	Average per yard.
Gross bullion..........................				
Less express..........................				
Net bullion to profit-and-loss report..........................				
Operating cost.				
Labor..........................				
Fuel..........................				
Power..........................				
Supplies..........................				
Upkeep of chain..........................				
Repairs:				
Digging appliances, labor..........................				
Digging appliances, material..........................				
Pumping appliances, labor..........................				
Pumping appliances, material..........................				
Gold saving and washing appliances, labor..........				
Gold saving and washing appliances, material......				
Electrical appliances, labor..........................				
Electrical appliances, material..........................				
Heating appliances, labor..........................				
Heating appliances, material..........................				
Hull and housing, labor..........................				
Hull and housing, material..........................				
Miscellaneous..........................				
Totals to profit-and-loss report..........................				

.... *Bookkeeper.*   .... *Manager.*

Statement of running time and delays, Conrey Placer Mining Co., Dredges Nos. 1, 2, 3, and 4, Jan. 1 to July 31, 1915.

Cause of delay.	Time, per cent.			
	Dredge. No. 1.	Dredge No. 2.	Dredge No. 3.	Dredge No. 4.
Clean-up	1.56	1.36	0.87	1.60
Moving ahead	3.89	6.33	2.75	3.80
Lines and spuds	3.42	3.01	2.25	2.95
Winches	.40	.41	.61	.13
Flume	....	....	.48	....
Ladder	.02	.14	.23	1.07
Tumblers	1.02	1.58	.70	5.91
Hopper	.16	1.24	....	.87
Grizzly	3.99	3.25	3.03	3.41
Bucket chain and drive	.62	3.05	2.52	2.27
Pumps and piping	.67	2.05	.38	.49
Electrical appliances	1.36	3.13	1.13	1.09
Heating system	....	....	....	.03
Débris	3.66	2.68	.36	.11
Power off	.68	.66	.53	.57
Stacker	.85	1.48	....	.41
Tables and sluices	.01	.39	.07	.97
Well	.02	.08	.18	.85
Gang plank	....	.06	....	.02
Unloading coal	.09	.15	.02	....
July 4	.71	.78	.78	.71
Hull and housing	.07	1.00	....	.01
Low water	.03	.38	....	....
Winter conditions	....	....	42.46	....
Funeral, President J. J. Myers	.01	.01	.01	.01
Miscellaneous	.02	.01	.02	....
Total delays	23.26	33.23	59.38	27.28
Total running time	76.74	66.77	40.62	72.72
Total time	100.00	100.00	100.00	100.00

OPERATING REPORT FOR ELECTRIC DREDGES.

The operating report for all the electric dredges, from their starting to July 31, 1915, showing the running time, yards excavated, and all operating costs, including repairs, is given in the table following. This is supplemented by a tabular statement showing the total yardage and all costs year by year. It also shows how the yearly expenses have been lowered.

Summary of yearly yardage and expenses, Conrey Placer Mining Co., Sept. 1, 1906, to July 31, 1915.

Year.	Cubic yards excavated.	Average operating costs per cubic yard, in cents.							Indirect expenses.[a]	Total.
		Labor.	Fuel.	Power.	Supplies.	Upkeep of chain.	Repairs.	Total.		
1906	322,174	1.65	0.08	1.59	0.20	1.40	1.07	5.99	3.80	9.79
1907	1,152,478	1.34	.06	1.34	.04	.87	1.12	4.77	2.63	7.40
1908	2,248,576	1.45	.08	1.69	.09	1.50	1.45	6.26	1.12	7.38
1909	2,429,524	1.60	.11	1.30	.09	1.69	1.89	7.61	1.22	8.83
1910	2,670,354	1.66	.13	1.29	.10	1.53	1.97	6.88	1.11	7.99
1911	3,566,691	1.29	.12	1.22	.09	1.31	1.80	6.11	1.04	7.15
1912	4,463,354	1.41	.17	1.34	.13	1.37	2.34	6.82	1.05	7.87
1913	4,625,436	1.37	.12	1.36	.09	1.09	1.93	5.96	.92	6.88
1914	6,268,626	1.13	.07	1.15	.09	.94	1.25	4.63	.73	5.36
1915[b]	3,632,677	1.13	.06	1.15	.08	.98	1.65	5.05	.94	5.99
Total	31,379,890	1.37	.11	1.32	.10	1.00	1.76	5.91	1.05	6.96

[a] Includes salaries, Ruby and Boston, insurance, taxes, maintenance of pole line and substation, roads, ditches, bonus to employees, legal expenses, accidents, all office expenses, etc., but interest on loans and other indebtedness is excluded.

[b] To July 31.

Operating report of Conrey Placer Mining Co., covering electric dredges Nos. 1, 2, 3, and 4, from starting to July 31, 1915.

Item.	Dredge No. 1.	Dredge No. 2.	Dredge No. 3.	Dredge No. 4.	Total.
TIME.					
Running hours, per cent	71	67	65	65	67
Lost hours, per cent	29	33	35	35	33
Total	100	100	100	100	100
EXCAVATION DATA.					
Cubic yards dredged, virgin ground	7,817,520	5,515,756	8,166,281	9,880,333	31,379,890
Cubic yards dredged, tailings [a]	72,678	752,240	479,872	145,192	1,449,982
Cubic yards dredged, gross	7,890,198	6,267,996	8,646,153	10,025,525	32,829,872
Average per running hour	174	132	161	420	195
Average per bucket	.18	.18	.19	.38	
Buckets per minute	15.75	12.98	14.15	18.62	
Average kilowatt-hours per yard	1.55	1.89	1.73	1.36	
Acres dredged	223.16	143.62	144.43	134.92	646.13
Average depth to bedrock, feet	22.1	28.1	40.8	45.3	
OPERATING COSTS, AVERAGE COST PER YARD, IN CENTS.					
Labor	1.50	1.68	1.75	0.79	1.37
Fuel	.11	.13	.13	.07	.11
Power	1.27	1.55	1.48	1.09	1.32
Supplies	.10	.11	.09	.09	.10
Upkeep of chain	1.03	1.49	1.51	1.08	1.25
COST OF REPAIRS, IN CENTS.					
Digging appliances, labor	0.19	0.32	0.28	0.23	0.25
Digging appliances, material	.32	.46	.62	.61	.51
Pumping appliances, labor	.04	.02	.03	.01	.02
Pumping appliances, material	.07	.03	.04	.01	.04
Gold saving and washing appliances, labor	.28	.28	.22	.17	.23
Gold saving and washing appliances, material	.60	.66	.36	.57	.54
Electrical appliances, labor	.04	.05	.05	.05	.05
Electrical appliances, material	.03	.04	.06	.04	.04
Heating appliances, labor	.01		.01		
Heating appliances, material	.02	.02	.02		.01
Hull and housing, labor	.01	.05	.04	.01	.03
Hull and housing, material	.01	.02	.01	.01	.01
Miscellaneous	.03	.03	.05	.02	.03
Total operating costs	5.66	6.94	6.75	4.85	5.91
Indirect expenses, excluding interest [b]					1.05
Grand total					6.96

[a] The tailings dredged are not used in calculating costs.

[b] In indirect expenses are included salaries, Ruby and Boston, insurance, taxes, maintenance of pole line and substation, roads, ditches, bonus to employees, legal expenses, accidents, all office expenses, etc., but interest on loans and other indebtedness is excluded.

The table last presented shows that over 31,000,000 cubic yards has been dug, with an operating cost of 5.91 cents per cubic yard and indirect expenses of 1.05 cents, or a total of 6.96 cents per cubic yard. It also depicts the nine-year struggle to increase yardage and lower working costs. The working costs commenced with 9.79 cents in 1906 and were reduced to 5.36 cents per cubic yard in 1914, in which year more ground was dug than in the first four years. The operating costs show that 1.76 cents per yard, or nearly 30 per cent, has been due to material and labor for repairs, and that power cost 1.32 cents, labor 1.37 cents, and upkeep of chain 1.25 cents. The item of upkeep of chain is not ordinarily shown in other dredging statistics, and as here given takes into account the initial cost of the chains and the repair work on them, such as the renewal of pins, bucket lips, and bushings, and is an endeavor to make monthly showings normal, the estimating being periodically checked and adjusted by actual cost expenditures.

OBJECT OF DETAILED COST STATEMENTS.

The Conrey company's main object in the keeping of such detailed cost statements is the guidance of their management in the reduction of expenses. In operating expenses all costs for unforeseen and unexpected accidents and shutdowns are included. The construction account has never been used to hide or confuse operating costs so that a favorable showing of working expenses might be given for short periods. The value of the figures given is that they represent periods from start to finish and do not represent exceptionally good or exceptionally bad showings.

FACTORS AFFECTING OPERATING COSTS.

To intelligently compare or estimate costs, much must be taken into consideration. Even in the same field with the same management and with similar dredges working a short distance apart, great variation has been found in operating costs owing to the differences in the nature of the ground dredged at particular times. In comparing operating costs in different districts after it has been established that working the gravel will pay, the main factors to be taken into consideration are as follows: (1) The nature of the ground worked; (2) the availability of water for power and dredging purposes; (3) the position and climatic conditions of the field of operations; (4) the relative costs of labor and supplies; and (5) the methods employed in estimating yardage.

NATURE OF GROUND WORKED.

Regarding the ground to be worked, various factors are involved, namely, the hardness of the gravel, the depth from water level to bedrock, whether the ground and the bedrock are level, the size of the bowlders, the hardness of the bedrock, and the amount of clay in the gravel.

The gravel at Alder Gulch and Ruby, although not as hard as the most compact and cemented gravel worked in the Oroville and Folsom districts of California, is far more difficult to dig than the average at these districts or that at Yuba, though not of the great depth of the latter. The size of some of the larger bowlders encountered by the Conrey company is shown in Plate IV, *A*, and when such bowlders are deeply imbedded in a clay matrix dredging is difficult, and serious breaks and delays are experienced. The bedrock in both districts is favorable for dredging operations.

WATER SUPPLY.

The water supply in Alder Gulch and Ruby for dredging is easily obtained and is abundant. Power is supplied by the Montana Power Co., which has extensive water-power works 26 miles distant and delivers power at about the same rate as that paid by companies in California. The voltage has to be transformed by the Conrey company from 46,200 down to 2,200 volts as used directly on the dredges.

CLIMATIC CONDITIONS.

The winter temperature of 25° to 30° F. below zero is a great handicap. The difficulties in winter of keeping the dredges working are vividly illustrated by Plates XXVIII and XXIX, *A*. The gravel near the surface is frozen and far more difficult to dig than in milder climates. The workmen are handicapped in many ways at their work, and the formation of ice on some of the sluice dredges dangerously reduces their flotation. In fact, if it were not for the necessity of keeping together exceptionally efficient and faithful workmen the advisability of continuing operations through the winter months would be doubtful. The Conrey company have been successful in keeping their stacker-type dredges constantly running through the winter months, owing largely to the heating of the dredges and the canvas housing of the stacker through which the heat from the dredge must pass, thus keeping free from ice the most important and the most exposed machinery. It was not possible to keep the *No. 3* dredge working through all the winters, especially in deep digging with a long ladder, and in consequence its operating costs were largely added to by the climatic conditions.

LABOR COSTS.

Compared to the labor costs of California, those at Ruby are considerably higher, and all men on the dredges work on 8-hour shifts.

METHOD OF COMPUTING YARDAGE WORKED.

The method of computing yardage as employed by the Conrey company is based on actual survey measurements made with much care. It has been found that the estimate of yardage by the number of buckets discharged, though automatically recorded, does not check with any close uniformity with the measurements, even though an adjusting coefficient is established by long working.

In view of the difficult nature of the gravel to be dredged, the winter conditions, and the extra labor costs, the showing that has been made with dredges that were more or less pioneers in the dredging industry is one productive of satisfaction, even when the lower costs in more favored districts are considered, especially as the struggles and mistakes of the past have beaconed the way to future improvement.

MISCELLANEOUS GOLD DREDGING IN MONTANA.

Outside the Grasshopper and Alder Gulch districts little gold dredging has been carried on in Montana. Attempts in various localities as given below have been made, but as yet with little success.

A dredge at Gold Creek was completed and started in the spring of 1905. It was a double-lift sluice-box dredge with buckets holding 5 cubic feet. It ran part of two seasons.

The Magpie Dredging Co. built a dredge at Canyon Ferry, about 19 miles from Helena, in 1910. It ran only part of two seasons.

The Kansas City Commercial Co. built a Marion dredge on Cedar Creek, about 10 miles from Iron Mountain, in 1910. This dredge has been operating intermittently ever since. It is a single-lift stacker dredge with a capacity of 7½ cubic feet.

In 1910 the British-Butte Mining Co. built a 5 cubic foot Risdon dredge about 4 miles from Butte, which ran only about six weeks on account of the low values in the material worked.

On Confederate Gulch, about 30 miles from Helena, a Risdon dredge operated for only about three months, when it was shut down on account of there being no values in the gravel.

In 1906 the Square Deal Gold Co. placed a small dredge on the Jefferson River about 12 miles from Whitehall. This dredge worked only 12 days, when it was abandoned owing to the low values in the gravel.

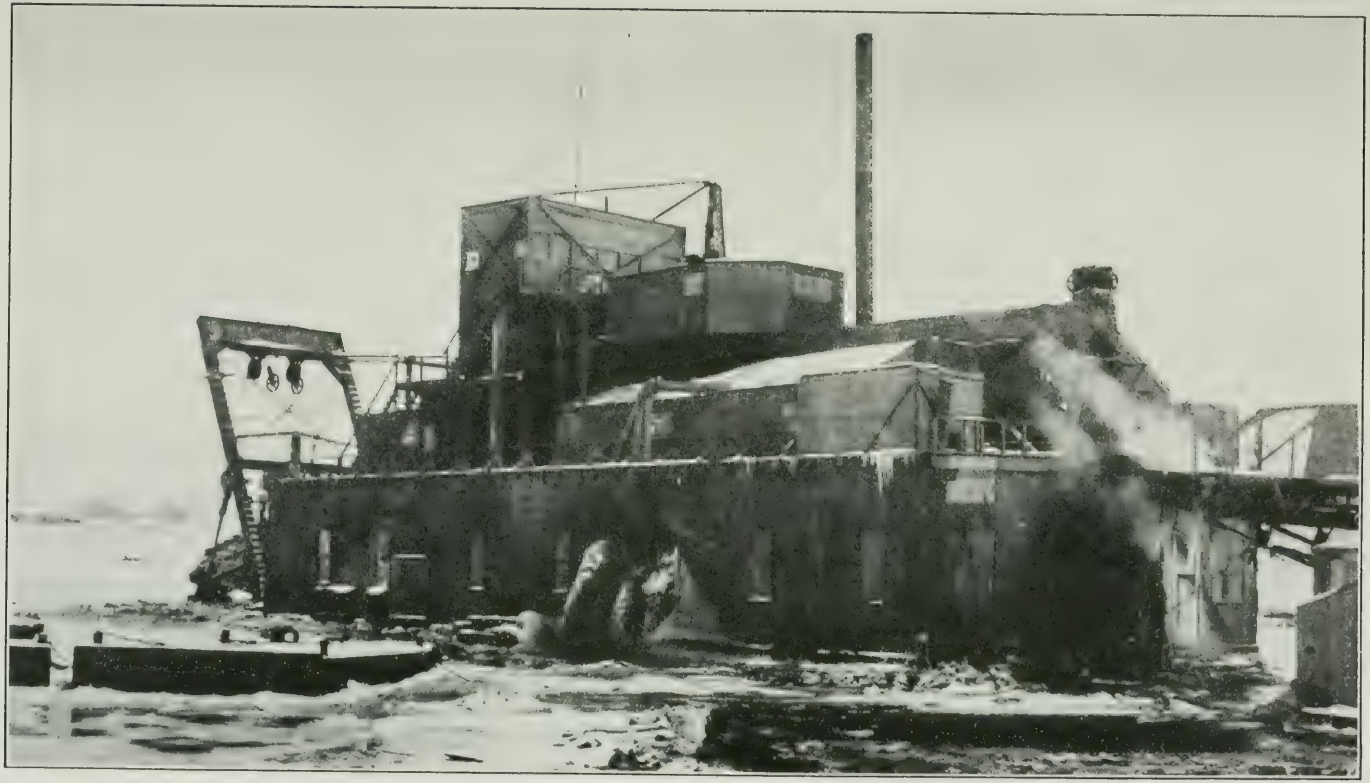
GOLD DREDGING IN PAN AMERICA.

Gold-bearing gravels in Pan America are known to exist. Fields have been exploited in the icy regions of Alaska; in such districts as Bannack and Ruby, more than 5,000 feet above the sea; in the genial lowlands of California; in the equatorial torrid regions of Colombia, and on the great Andean Plateau of Peru.

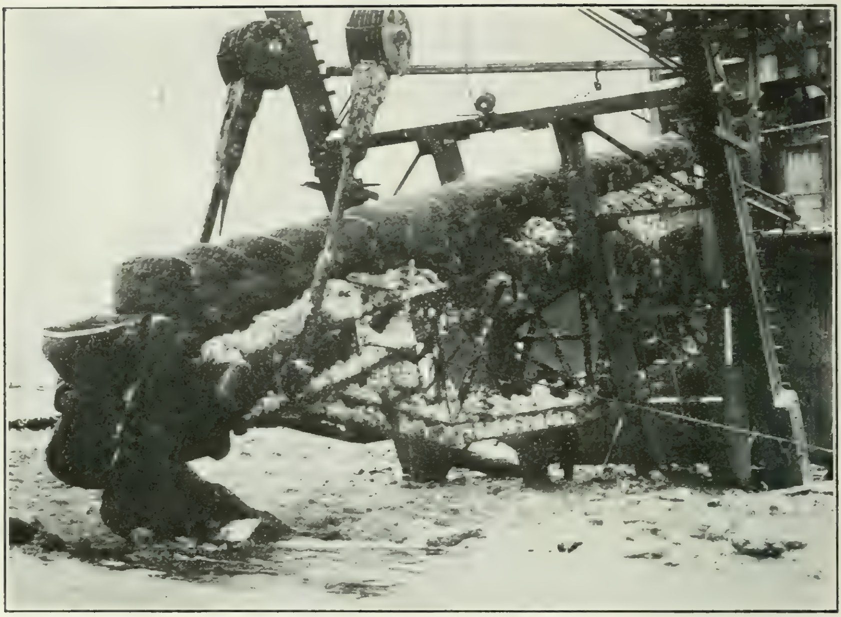
In the United States the limitations of the gold dredge, as well as the dredging fields, are fairly well known; in South America they are not so well known and may have great future development.

GENERAL REMARKS ON GOLD DREDGES.

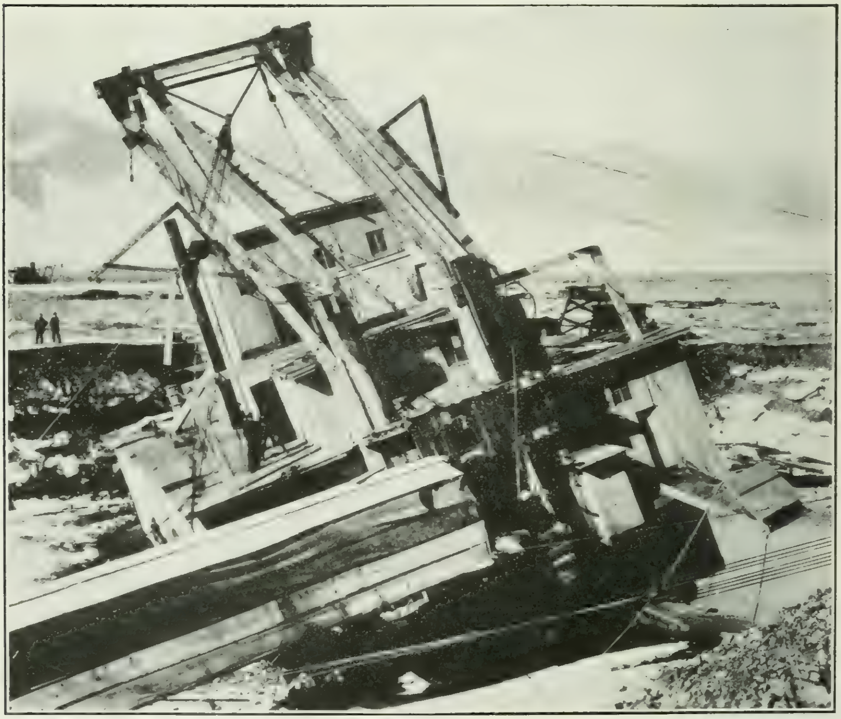
The story told by the dredging operations in Montana is to the effect that the gold dredge has been the last resort of the placer miner and that it is capable under right conditions of doing some extraordinary work. The extent of the development of dredging



WINTER CONDITIONS, NO. 3 DREDGE.



A. BUCKET LINE, NO. 3 DREDGE, IN WINTER.



B. CONREY NO. 2 ELECTRIC DREDGE AFTER ACCIDENT, AND WITH WATER PUMPED FROM POND.

in Montana in 20 years can not be better illustrated than by the careful examination of the photographs of the *Graves* and the *Maggie Gibson* dredges, with their total weights of 450 tons and 100 horsepower each, and by a comparison of them with the Conrey *No. 4* dredge weighing 2,000 tons and having 1,285 horsepower.

Conditions resulting in low dredging costs have already been discussed. Small dredges may be required in one locality and large ones in another. The very largest dredges with their enticing showings of very low costs should be tried only under most favorable conditions and with sufficient areas of gold-bearing ground to permit the operations to be conducted for a period long enough for the redemption of the capital required for the construction not only of the dredges but of extensive machine shops, transformer station, etc., and still allow ample margin to make good initial mistakes and miscalculations. During the 16 years' work of the Conrey company there has been a constant struggle to obtain lower costs by bigger digging and by stronger and better appliances.

Dredging appliances satisfactory and strong enough under certain conditions in one region when transferred in body or principle to the Alder Gulch fields, had to be strengthened or modified to meet the local conditions. It has been seen that the yardage dug by a dredge is largely in proportion to the horsepower used, and as the size of buckets and the horsepower have been increased, new difficulties have presented themselves in making strong enough the various other parts and details. It would appear that at last a high-water mark has been reached in gold-dredge construction, but this is by no means certain.

True, in the future there is no such great opportunity of development and improvement as has been possible in the past, still no two dredging fields are alike, and each must be planned for on its own basis; and it takes time and patient effort to adapt the best appliances to new conditions. It is a most dangerous practice to figure the working expenses of one region by another unless all conditions are identical, or to imagine that at the start of a new enterprise it is possible to obtain as low a working cost at once as had been achieved in another region only after years of progressive and strenuous effort.

Outside the practical economic considerations involved, it appears to the writer that the development and record working of a great gold dredge has a very far-reaching and ethical meaning. The *No. 4* Conrey dredge may be taken as an example. This dredge was the product of no one locality, the child of no one brain, but rather the result of persistent and progressive effort in all dredging fields and machine shops, extending over nearly 20 years, and behind these efforts were the scientific and inventive discoveries of the age. Its record month's work of 400,000 yards, or 600,000 tons, depth of 54 feet, must be considered in connection with the statement that the total number of men at work on this dredge was only 10 in all.

Yet, with the mighty steel and electrical tools at their command and the force chained to service from waterfalls 26 miles distant, these men on the firing line and supported by the machine-shop reserves could each be accredited with having raised 2,000 tons of gravel, some of it from a depth of 54 feet below water to 40 feet above; then sorting the gold-bearing gravel from the barren, spreading it out on gold-saving tables, extracting the gold, and then elevating and stacking the waste in such a way that future operations were in no way impeded, and all for an operating cost of about 3 cents a ton, and this in eight hours.

How many men with mere muscular energy at their command and primitive appliances would it have taken to do this work? To the writer it would appear that the miner, mechanic, metallurgist, chemist, engineer, and scientist have increased the laborer's power in this instance a thousandfold and created for him work necessarily abandoned under old conditions.

ACKNOWLEDGMENT.

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PLACER-MINING METHODS AND OPERATING COSTS.

By Charles Janin.

INTRODUCTION.

The first work in placer mining was done with some form of the ordinary gold pan or of the Mexican batea. Although such a device is still necessary in sampling of placer deposits and for like uses, its capacity is hardly such as to warrant serious consideration of its use as a method of placer mining.

An ordinary gold pan will hold about 20 pounds of material and is roughly estimated to contain one one-hundred-and-fiftieth of a cubic yard. The number of pans an ordinary miner could wash in a day is probably 45 to 100 or more, depending on the material handled and the care taken in saving gold.

In the early days of placer mining the rocker or cradle and the Long Tom were invented. The rocker is too well known to require description. The Long Tom is a short sluice box. With a rocker, under average conditions, the working of 2 cubic yards would be a fair day's work. With the Long Tom, as with the sluice, the output depends on the quantity of water available, the grade of the sluice, the character of the material, and like factors.

"Shoveling in," or hand sluicing, is the term applied when miners, after having picked out the large stones, shovel the material into a sluice supplied with running water. Here, as with the Long Tom, output depends on conditions. The grade of the sluice may range from 2 to 20 inches per box of 12 feet, and the size may vary according to the amount of water available.

As an indication of the gold recovery sometimes obtained from hand sluicing, one operator in Alaska informed the writer that with 12 men shoveling into sluices he cleaned up $8,000 a day during part of the first season's operations. Unfortunately the whereabouts of any more ground of this quality is unknown, at least to the writer. The cost of sluicing may vary from 20 cents to $1 a cubic yard, according to the wages paid and the conditions encountered.

EARLY PLACER MINING.

Browne [a] writes of early placer-mining operations as follows:

> Many of the ancient channels and benches, especially those of the earlier period (in California), were exposed in complete cross section by the erosion of the modern

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[a] Browne, R. E., Ancient beds of the Forest Hill Divide: Tenth report of the State mineralogist, California, 1890, pp. 435–465.

streams. For some time after the first discovery in 1851 the mining of the district was practically confined to these exposed sections. The methods were naturally ground sluicing, hydraulicking, and drifting direct upon the richer layers. The drifting extended farther into the hill, and deeper tunnels were driven to drain off the water and facilitate the delivery of the gravel.

The exposed and easily accessible deposits were gradually exhausted, and bolder enterprises were started. Shafts were sunk through the volcanic cap, and deeper systems of channels were discovered. Large quantities of water were encountered, and this method of attack was found too expensive. Finally, the important mines were worked through deep drain and tramway tunnels driven at great expense through the bedrock. Upraises to the gravel bottom were made at intervals and the richer gravel extracted. According to the firmness of the cementing substance binding the pebbles together, the gravel was either washed through sluices or crushed in a stamp mill.

OPERATING COSTS AT FOUR PLACER MINES.

The output of gravel from a drift mine is generally measured by carloads. The size of the cars used is not uniform so a comparison must take this difference into account. The cost of breaking gravel, independent of the expenses of subsequent handling, or of those connected with the opening of the drifts and gangways, timbering, and track, is controlled by the hardness of the gravel, the expense for powder and candles, and the rate of miners' wages. The operating costs at four mines mentioned by Browne ranged from $1.10 to $3.25 a ton, not including management, improvements, nor dead work during periods of nonproduction. The yield was from $1.75 to $10 per ton. The most recent data available in California show costs of drift mining ranging from $1 to $2 a ton. On the Seward Peninsula, Alaska, drift mining costs in frozen ground have exceeded $4 a ton.

DETAILS OF OPERATION OF RED POINT MINE.

The following extract from Browne's[a] description of work at the Red Point mine is of sufficient interest to warrant repetition:

Pay channel.—Fairly uniform in general course and grade, though irregular in width and depth of gravel and in pay.

Gravel.—Cemented, involving the use of a large amount of powder in breaking, and a small expense in timbering. Gravel worked by washing, though not so free as Hidden Treasure gravel.

Method of attack.—The channel is reached through 2,000 feet of bedrock tunnel, and upraises 20 to 40 feet to channel bottom. Grade of tunnel, uniformly 3 inches in 100 feet. Distance trammed from gravel breast to washing floor on surface, 4,000 feet. The gravel is breasted by drilling and blasting, and is shoveled into cars and pushed by hand to the chute. Cars having a capacity of 1 ton each are loaded at the chute and hauled by horses to the washing floor at the mouth of the tunnel.

Bedrock tunnel.—Size, 7 by 8 feet. In order to push the tunnel ahead rapidly, a compressor plant is maintained to drive air drills. Two air drills are run in the face. Blasting, with No. 2 dynamite powder. Very little timbering.

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[a] Browne, R. E., Op cit., pp. 456.

Gravel breasting.—Usually the entire body of gravel about 100 feet wide and from 2 to 12 feet high is breasted from bedrock to volcanic cement, the latter forming a clear roof to work to. Drilling, single hand. Blasting with No. 2 dynamite powder. The method of timbering is the same as in the May Flower. Sets 6 or 7 feet apart. Where the gravel is deep and the pay does not warrant the removal of the entire quantity, the timber is closer and heavier, to prevent the upper layer of gravel from flaking or slipping at the contact-surface with cement.

Powder.—The amount used in the work in the channel in breasting the gravel is one-half pound per ton of gravel.

Ventilation.—No. 4 Baker blower run by small steam engine in compressor building. Air-pipe, 11 inches; cost, 45 cents per foot.

Washing the gravel.—Length of dump house, 50 feet. Depth from car track (tunnel level) to washing floor, 30 feet. Storage capacity, 400 tons. Size of nozzle, 3 inches. Water pressure at the nozzle, 25 feet. The sluice boxes are 18 inches wide and 12 feet long, and have a grade of 18 inches to the box.

The line of sluices is as follows: Beginning at the dumping or washing floor; 200 feet Hungarian and flat riffles: drop, 30 feet; 24 feet wooden block and rock riffles; 65 feet ground sluice; 140 feet block, rock, flat, and Hungarian riffles; 680 feet canõn bed; drop, 20 feet; 75 feet ground sluices; drop, 6 feet; 40 feet ground sluices; 80 feet, 24-inch flume; 300 feet ground sluices; dam; 40 feet double 30-inch flume; grizzly and undercurrent, with fall of 15 feet; tailings accumulate in canon below. The lower riffles are charged with quicksilver.

Clean-up.—The upper four boxes are cleaned up two or three times per week; the following 340 feet of riffles, once a month; the balance, four or five times a year. The tailings in the canyon are sold to the highest bidder.

The total cost of surface plant and improvements, including compressor plant, boarding house, office, and dwelling, blacksmith shop, stable, powder house, wood shed, framing shed, snow sheds, 1½ miles of graded wagon roads, trails, graded yard, dump house, tank, sluices, 1½ miles of 7-inch pipe for water supply, four horses, etc., about $22,000.

Fifty men were employed, 25 being white men and 25 Chinamen. The average wage was $2.40 a day. One hundred tons of gravel was handled daily and the operating costs averaged $2 per ton of gravel, or approximately $3 per cubic yard, not including management and overhead charges.

In working gravel deposits by hydraulic mining it is essential that an abundant supply of water under sufficient head can be economically developed and that there is sufficient grade for sluice boxes and for disposing of the tailings. Without dumping facilities straight hydraulic mining is an impossibility. The gold content of much of the gravel hydraulicked in California was surprisingly low. The recovery from 3,250,000 cubic yards worked at the Malikoff mine in Nevada County in 1870–74 was 2.9 cents per cubic yard and from 43,000,000 cubic yards at Gold Run mine, Placer County, the recovery averaged 4.8 cents per cubic yard. The gold content at La Grange mine, Trinity County, is from 3½ to 5 cents per cubic yard. It can be seen that, in order to profitably handle gravel of such low gold content, vast quantities of material must be moved at a low operating cost in order to amortize the initial investment. In order to obtain sufficient head, it is often necessary to bring water from a great distance. One company, with 290 miles of ditch, 8 miles of pipe, etc., spent $2,000,000 on its plant, and a number of the California companies operating before the débris laws put a stop to their activity spent from $200,000 to $500,000 in preparing for work.

DATA ON COST OF HYDRAULIC MINING.

Hydraulic-mining cost may range from 2½ cents per yard in California under exceptionally favorable circumstances to 12 or even 20 cents at Atlin, B. C., and to 25 cents or more in Alaska, according to the conditions of operation, and where frozen gravel is encountered and where it is necessary to elevate, the gravel costs frequently exceed 60 cents a cubic yard. Regarding costs of hydraulic mining, Radford[a] presents the following data on a hydraulic mine in northern California:

> The season commenced in November, 1899, and ended the last of July, 1900. During this time, 655,657 miners' inches (an inch equals 1,728 cubic feet in 24 hours) of water were used for piping, and for sweeping the bedrock at the end of the season. From actual surveys, this amount of water washed down 1,251,399 cubic yards of material, consisting of pay gravel lying on the bedrock, and varying in thickness from a few inches to 8 feet, and practically barren top material, consisting of mountain slide, carrying considerable broken rock, clay, and soil. The banks varied in height from 50 to 130 feet, the average height being 63 feet. The grade of the sluices was 7 inches to 12 feet, the boxes being paved with block riffles 12 inches deep. Long bedrock cuts extended from the heads of the sluices to within a few feet of the banks, and were kept practically to grade as the work advanced. At first, electric drills were used on this work, but as it was found that heavy blasting shattered the rock too much, and caused slips, these drills were abandoned and hand drilling was substituted. The total cost was made up as follows:

Data on cost of hydraulic mining at mine in California.

	Total cost.	Cost per cubic yard.
Care of ditch, reservoir, and siphon: Labor, $2,670.99; supplies, $115.55	$2,786.54	$0.00223
Washing (piping)	2,401.05	.00192
Drilling in bedrock cuts: Hand drilling, $1,050.91; electric, $269.62	1,320.53	.00105
Timbering bedrock cuts	157.39	.00012
Electric lighting	598.62	.00047
Sluice building and repairing: Labor, $1,045.70; supplies, $35.50	1,081.20	.00086
Blacksmithing	644.02	.00051
Cleaning up	968.79	.00077
Moving pipes and giants	898.85	.00071
Breaking rocks and clay	6,124.91	.00490
Clearing ground for piping (cutting brush)	158.37	.00012
General expenses, watching sluices and odd jobs	3,088.69	.00250
Supplies used in mine	3,015.37	.00241
Taxes, office expenses, surveying, salaries	4,267.31	.00341
	27,511.64	.02198

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[a] Radford, W. H., Hydraulic mining in low-grade gravel: Pacific Coast Miner, vol. 7, 1903, p. 80.

DETAILS OF OPERATION OF LA GRANGE MINE.

The best known hydraulic mine in California, and the largest now operating in the world, is La Grange mine in Trinity County. The operating company now has a water system of 29 miles of main ditch, flume, tunnel, and siphon, 7 miles of 30-inch water-pipe line, and 14 miles of auxiliary ditch not now in use. This is supplied with all necessary reservoirs and connections for bringing the water to the face of the pit, and with the dam at the lower lake represents an outlay of approximately $700,000. Twenty-eight men, including the boarding-house force, are employed at the mine.

The method of operating is as follows: Water is brought from the mine reservoirs in two 30-inch pipe lines and discharged against the gravel bank through giants under a head of 600 feet. Either two 8-inch or one 8-inch and two 6-inch nozzles are used at one time. These combinations require 4,000 to 4,200 miner's inches of water, and they usually empty the mine reservoirs in six hours. The water is then shut off from the pipes and the reservoirs are allowed to fill, requiring generally four hours when the full head of water is in the ditch; during this time the pipe men drill and blast the large bowlders and hard pieces of cement rock in the pit.

Bowlders of 1 ton and 2 tons weight at times pass through the sluice, though such large bowlders are generally blasted in order to save water. The cemented gravel is disintegrated usually before it leaves the pit, and little or none is found on the dump. At the usual rate of operation, the pipes wash down and send to the sluice 1,000 cubic yards of material per hour. The sluice box is 6 feet wide by 5 feet deep and is lined with 40-pound steel rails set transversely 5 inches apart on the bottom and longitudinally on the side and held in place by lugs and bolts.

Quicksilver is sprinkled in the upper part of the sluice every few days.

The sluice is 2,400 feet long. Seventy-five per cent of the gold is found in the first 540 feet, and only the first 1,300 feet is cleaned annually, so little gold getting down to the remainder that it is not worth cleaning up oftener than once in two years. The great length of sluice is necessary to carry the tailings to the edge of the dump. At 1,300 feet it branches into two parts in order to distribute the débris over the width of Oregon Gulch. Each year it is necessary to add about 50 feet to the lower end of each branch. The amount added to the upper end varies with the slope of the bedrock and the movement of the gravel mass.

Working costs vary for different seasons from 2.8 to 3.5 cents per yard, the percentage of cost being distributed approximately as follows:

Distribution of costs of working La Grange mine.

Item.	Per cent.
Maintaining ditch	18
Washing, gravel piping	9
Sluice maintenance	25
Breaking bowlders	9
Pipe lines and giants	7½
Roads and buildings	3½
Clean-ups	1
Administration	8½
Taxes	3
Teaming	5
Boarding house	8
Various	2½

HYDRAULIC MINING AT ATLIN, B. C.

The following data, including average operating costs, regarding hydraulic mining at Atlin, B. C., for the seasons 1910 to 1913, are quoted from Hughes.[a]

Data regarding hydraulic mining at Atlin B. C.

	Pit 1.	Pit 2.
Possible running time, days per season	184	180
Actual running time, days per season	154	141
Cubic yards worked per season	283, 300	178, 580
Cubic yards per day per season	1, 540	992
Cubic yards per day for time running	1, 840	1, 266
Miners' inches used per day	4, 500	4, 250
Yards per inch per day of running time	.41	.30
Average depth of ground, feet	60½	16⅓

Average cost per cubic yard, cents.[b]

	Pit 1.	Pit 2.
Labor	7. 34	13. 29
Powder	1. 40	1. 96
General operations	2. 18	3. 03
Ditch maintenance	. 22	. 35
General expense	. 44	. 70
Royalties, rental, etc	. 49	. 64
Total	12. 07	20. 01

If there is lack of grade for a dump and if sufficient water is available, a hydraulic elevator may be employed; otherwise a mechanical elevator may be used. A description of the different types follows subsequently.

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[a] Hughes, A. D., Hydraulic mining at Atlin: Min. and Sci. Press, vol. 110, Apr. 24, 1915, pp. 647–654.

[b] Boarding house included in labor. "General operations" includes supplies, teamsters, blacksmiths, and other operating expense not directly chargeable to either pit. "General expense" includes traveling, offices, etc.

ARTIFICIAL HEAD FOR HYDRAULIC MINING.

At different times attempts have been made to create an artificial head for hydraulic mining by pumping water to a reservoir from which it could be drawn for hydraulic operations as needed or when available. All projects of this kind coming under the observation of the writer were financial failures, though a few of them could perhaps be classed as mechanically successful. One such plant cost over $500,000. Water has also been furnished for hydraulic operations under artificial pressure, as in the case with the pump sluice dredge described further on. The disadvantage is obviously the expense of pumping.

With hydraulic elevators the capacity of the elevator depends on (1) the effective head and volume of water; (2) the proportion of the lift to the head; and (3) the regularity of operations.

The maximum size of gravel that can be elevated is controlled by the size of the throat of the elevator. Large bowlders can be stacked to one side, and at times a short grizzly is arranged so that the undersize will pass to the throat of the elevator; the larger gravel can be conveniently stacked by a derrick.

HYDRAULIC MINING AT RIVER BEND MINE.

Costs of working gravel banks with water under pressure and elevating the material with hydraulic elevators will vary greatly in different localities. The following data regarding hydraulic mining at the River Bend mine are taken from Theller.[a]

The River Bend mine is on the Klamath River, Siskiyou County, Cal. The water is obtained from two sources; one ditch supplies the water for the giant, the other for the elevators. The supply system includes 11 miles of ditches and 1½ miles of flume.

There are two Joshua Hendy giants with 3½-inch nozzles, which consume about 525 cubic feet per minute, working at an effective head of 90 to 100 feet. A Campbell elevator having a 10½-inch throat and using approximately 560 cubic feet of water per minute under an effective head of 325 feet raises the material 46 feet vertically. The elevator is set in a sump 10 feet deep and at an inclination of 70°, the height of the gravel bank being 30 feet.

The following table is made from daily averages throughout the season of 1912–13. The working costs do not include administration charges.

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[a] Theller, J. H., Hydraulicking on the Klamath River: Min. and Sci. Press, vol. 108, Mar. 28, 1914, pp. 523–526.

Data on production and operating costs, River Bend mine.

Cubic yards of gravel washed per day	417
Cubic feet of water used per minute for giants	525
Cubic feet of water used per minute for elevator	560
Cubic feet of gravel lifted per minute	7.81
Cubic yards of gravel washed per miner's inch (giant water)	1.19
Grade of sluice, inches in 12 feet	7
Operating costs per cubic yard, not including administration, cents.	8

HYDRAULIC MINING AT LOGAN MINE.

At the Logan mine, near Waldo, Oreg., with 40 cubic feet of water a second, 15,000 to 30,000 cubic yards of gravel is washed per month. Four giants are used, two in the pit and two on the tailings dump. A 20-inch hydraulic elevator with two lifts elevates the material 49 feet. The gravel is easily washed, there are no large bowlders, and the operating expenses are said to be only 3⅞ cents per cubic yard under exceedingly favorable conditions.

THE RUBBLE ELEVATOR.

The rubble elevator is a machine that has attracted some attention of late years for the working of gravel deposits, unsuitable for dredging, where water is available for hydraulic installation but where the dump facilities are insufficient for an easy removal of tailings. A plant of this type has been described by Haley.[a]

The principle of the rubble elevator, which was developed in Oregon, is simple. It consists of an approach or apron running from the bedrock up into the elevator, which is an inclined trough, on a 17° pitch, 80 to 100 feet long and 8 feet wide, with sides tapering from 12 feet high at the bottom to 6 feet at the upper end. In addition to the apron, which is 10 feet long, the first 20 feet of the incline is solid and lined on the bottom and sides with ⅜-inch steel. From these solid plates to the end of the incline are grizzly bars of timber 2½ by 6 inches, placed 2½ inches apart and covered with steel bars ⅜ inch thick. The fines from the grizzly pass to the sluice box, which extends from the grizzly to one side of the machine.

METHOD OF OPERATION AT RED HILL, CAL.

The method of operation of one of these machines at Red Hill, Cal., is as follows: The elevator or drive giant is set about 80 feet in front of the elevator. The field giants deliver material to the front of the elevator, and the material is then handled by the elevator or drive giant. In the operation of the elevator giant skilled "pipers" are required, as careless or inexperienced handling of the giant may cause fine material and some gold to be driven through the elevator. The elevator is moved to a new location as often as necessary, the frequency depending on local conditions. Care must be taken each move to see that there is plenty of dump room. The fines, of course, pile up at the end of the sluice and must frequently be piped back, and when water is available the coarse material in the dump is also piped back.

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[a] Haley, C. S., Elevating 10-cent gravel at a profit: Min. and Sci. Press, vol. 104, Apr. 13, 1912, pp. 530–532.

The following details of the operations at Red Hill will give some idea of the capacity of the machine. The depth of the bank was 20 to 25 feet, the gravel ores containing large bowlders up to 5 tons. Water was furnished under a pressure of 450 feet to two No. 3 giants. The capacity with 600 to 1,000 inches of water was 1,000 to 1,200 cubic yards a day, and on one run 10,000 yards was put through the machine at an operating cost of less than 5 cents per cubic yard.

MISCELLANEOUS EXCAVATING DEVICES.

The economic excavating and washing of gravel by mechanical means other than dredging where water for hydraulic mining is not available present a difficult problem. Many machines have been designed to take the place of the gold dredge, especially in working areas too small to warrant the expense of building a dredge. As a matter of fact, most attempts to mine placer deposits by mechanical means other than dredges, except where the ground has had an unusually high gold content, have been economic failures.

STEAM SHOVEL AND BUCKET-ELEVATOR DREDGE.

With the exception of the bucket-elevator dredge, the most successful excavating machines used in gold placer mines are the ordinary steam shovel and the drag-line bucket excavator with the bucket working on a boom. Both of these machines are used to advantage in digging canals for irrigation and drainage. There the question of handling the material presents no great difficulties; the only problem is to obtain an efficient digging machine, as the disposition of the material dug on either side of the cut is a simple matter.

In placer-mining operations, however, these machines have rarely proved a success, on account of the heavy cost of operation. Where tried in California the cost of placer mining by this method has been 17 cents or more per cubic yard. In other localities steam-shovel costs have been placed at 5 cents per cubic yard, but no mining that has come under the observation of the writer has ever been done for any such figures. At the rock-crushing plants steam shovel and delivery costs in handling dredge tailings amount to approximately 6 cents a cubic yard. At the large "porphyry" copper mines the total cost of steam-shovel work in shipping and moving surface material runs from 20 to 35 cents per cubic yard, and the writer would not care to consider the installation of a bucket excavator in placer mining unless the physical conditions of operations were very favorable and the gold content was more than 20 cents per cubic yard, and only then provided that no more efficient form of mining seemed feasible.

EXCAVATING MACHINE TRIED IN CALIFORNIA.

Following is a description of a machine that operated one or two seasons in California: The machine rested on rollers by which it was moved on a plank track. The bucket delivered the excavated material to a set of trommels and gold-saving tables, similar to those of a dredge. The excavating bucket had a capacity of 1½ cubic yards and worked on a boom 60 feet long. The bucket was raised and lowered by means of a cable working over a sheave at the end of the boom and was loaded by means of a drag line traveling between sheaves on front of the floor plate. Dumping was accomplished by means of an auxiliary cable attached to the front of the bucket.

The machine was turned by a single-drum winding engine having two cables attached, whereby a complete circle could be made and the scraper or excavator bucket operated on all sides. Steam was used for power with wood as fuel. The machine excavated gravel to a depth of 35 feet. The gravel was dumped into a hopper 12 by 12 feet. The hopper fed a trommel screen 4.5 by 22 feet with ⅜-inch perforations in the upper part and ¾ inch in the lower 18 inches. The oversize was discharged to a belt-conveyor stacker, and the undersize passed over Hungarian riffles to a riffler sluice box, where quicksilver was used, and finally to a 20-foot sluiceway, lined with cocoa matting.

The cylinder and stacker were operated by a 15-horsepower electric motor, and the whole washing apparatus was mounted on rails. Three men were required to operate the apparatus—two on the excavator and one on the washer. The operating cost was said to approximate 17 cents per cubic yard.

OPERATION OF EXCAVATING MACHINE IN SIBERIA.

At the Kolchan mine in Siberia a similar type of machine was tried with some success on rich gravel tailings from early operations, the gold content of which was in excess of $1 per cubic yard. This machine first delivered to straight sluice boxes and afterwards to a trommel and gold-saving tables built on a floating scow. Although for several seasons an operating profit was made on account of the high gold content of the material handled, it was finally decided to remodel the scow into a 3½-foot bucket elevator dredge by increasing the size of the pontoon and adding the digging end of a dredge to the washing apparatus of the scow. With this dredge double the quantity of material was handled at less than one-half the operating cost, demonstrating the greater efficiency of the continuous bucket line when on a floating dredge as compared to the single-bucket excavator.

ELEVATORS WITH CONTINUOUS BUCKET LINES.

Mechanical elevators made with continuous bucket lines have been tried on various fields. A number of years ago one was tried on Bonanza Creek in the Yukon. The gravel was elevated from a sump by a close-connected line of 3-foot buckets and delivered to a sluice box placed at right angles to the lift. The capacity of the elevator was something more than 1,000 yards a day, but considerable trouble was experienced with the pumps. These raised the water from the sump and would frequently become clogged with roots, etc. Another difficulty was the lack of mobility of the plant and the time required to move it to a new setting. The elevator required 50 horsepower and two pumps, one of 12-inch and the other of 8-inch capacity, took 100 and 50 horsepower. The gravel was hydraulicked to the sump and then raised by the elevator. The method of treatment was expensive and the machine was afterwards replaced with dredges which operated at considerably lower cost.

An elevator designed on somewhat similar lines but with several improvements was built at Beauce, Canada, at a cost of $25,000. This operated a short time but was soon discontinued for lack of sufficient gold content in the gravel. Operation costs were stated to be 15 cents a yard.

EXCAVATOR CONSTRUCTED NEAR SMARTSVILLE, CAL.

An ambitious excavator on the same order has been described by the author.[a] This was built near Smartsville, Cal., and entailed an outlay of more than $200,000. The proposal was to hydraulic the gravel to a sump on the front part of a stationary dredge building of concrete and sheet iron, where a regular dredge digging ladder, equipped with fifty-two 7 cubic foot buckets was to elevate the material to a revolving screen 45 by 6 feet. From the screen the undersize was to pass to gold-saving tables having an area of 4,600 square feet and fitted with Hungarian riffles, and the oversize was to pass to belt conveyors 570 feet long and from there to overhead tramways. Various treatments were proposed for the fines, but the plant never started operations, as the company got into difficulties and it occurred to the new management that it might be well to ascertain the gold content of the material to be handled, a thought that had evidently not occurred to the promoters of the enterprise. This investigation proved the folly of the whole enterprise, aside from any of the mechanical eccentricities proposed.

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[a] Janin, Charles, Present-day problems in California gold dredges: Trans. Am. Inst. Min. Eng., vol. 42, 1911, pp. 855–872.

RADIAL CABLEWAY.

At Ruby, Mont., the first mining operations of the Conrey Placer Mining Co. were undertaken with what was termed a "radial cableway" with self-filling bucket. (See pls. VI, *B*, and VII.) It was thought that this machine would solve the following problems presented by flat placers of low grade: (1) Excavation at low cost; (2) delivery of material at sufficient elevation to use a sluice of ample length and grade; (3) delivery of tailings high enough to provide sufficient dumping room.

The arrangement consisted of a central or pivot tower, provided with a large hopper placed 40 feet from the ground which delivered the excavated gravel to a sluice 30 inches wide and 200 feet long, built on a 5 per cent grade. This tower was built with a ball-bearing top, arranged to turn on its axis. The traveling head tower was placed on a curved track about 400 feet from the pivot tower and arranged to move through an arc of 180°. This tower carried the engine boiler and cable anchorage.

The excavation was made along radial lines and a semicircular or fan-shaped pit was worked out around the hopper or pivot tower which stood on bedrock in the pit previously worked out. After each pit was excavated, the entire plant was moved forward and another pit commenced.

The bucket struck the ground teeth first, settled down on its bottom and as the carriage continued towards the head tower, with the hoisting line slack, the bucket was automatically locked and ready for digging. The bucket filled readily and was then hoisted and automatically dumped into the hopper at the pivot tower. Water for washing the material was supplied under gravity through a 12-inch pipe. The bucket had a capacity of 1½ cubic yards and under favorable conditions it was claimed that as many as 400 buckets were filled in 10 hours. Five men—leverman, fireman, signalman, hopperman, and rigger—were required to operate the machine.

The handling of the large bowlders gave considerable trouble, and labor was expensive, and the work was discontinued in 1900 without showing any net profit. The total expenditure in connection with the equipment amounted to $27,000. The machine handled a total of 350,000 cubic yards at a cost of approximately 27 cents per cubic yard.

Somewhat similar work has been attempted at different times with drag-line buckets attached to a cable way in northern California and in Oregon and Alaska, the cost of operation being about 25 cents or more a cubic yard.

BEACH MINING.

A form of gold mining somewhat peculiar to the Pacific Coast is the method used in mining the heavy black sand of the ocean beaches, especially near the mouths of rivers draining areas that carry auriferous gravels. These beaches are worked intermittently, more particularly after storms when the overburden of ordinary beach sand has washed away, leaving the black and heavier sand behind. These sands are washed in toms or sluices or are handled by concentrators. Repeated efforts to mine these sands on a large scale have met with failure and the output of gold and platinum from this source is not of great importance.

DRY PLACERS.

In the report on mineral resources of the United States for 1912, issued by the United States Geological Survey, considerable attention is given to dry placers, and persons interested in the matter are referred to the report.[a] The following abstract from a paper by Knox and Haley [b] is thought sufficient for this paper.

In certain arid districts, notably Australia, northern Mexico, Lower California, and parts of the States of California, Arizona, and New Mexico, there are deposits of so-called dry placers. Most of these consist of gravel, but some detrital deposits occur. Economically, dry placers are not of great importance, but native miners, with small hand-blowing machines, often win a fair day's pay.

Most of these deposits are shallow and are somewhat cemented by limonite, and their gold content is unevenly distributed; that is, they are patchy. Many are of considerable extent. Serious attempts have been made of late years to work them on a large scale. Notably a group of claims in southern California was recently offered in London. The claim was made that the gravel would average $1 per cubic yard. However, a careful investigation of the method of sampling showed that most of the samples had been taken from gravel exposed in gullies and waterways leading down from an escarpment. In sampling any alluvial, exposed faces like these must of course be avoided, as there is in them a concentration due to the rains, and gravel taken from them is in consequence not representative of the deposit.

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[a] See Heikes, V. C., Dry placers in Arizona, Nevada, and New Mexico: Mineral Resources U. S. for 1912, U. S. Geol. Survey, 1913, pp. 255–262; Yale, C. G., Dry placers in California: Op. cit., pp. 262–263.

[b] Knox, N. B., and Haley, C. S., The mining of alluvial deposits: Mining Mag., vol. 12, Apr., 1915, p. 211.

RECENT USE OF STEBBINS-QUINNER MACHINE.

The most serious recent attempt to work placer deposits with air-blowing machines has been by means of what is known as the Stebbins-Quinner machine, made in Los Angeles, Cal. After having been dug by a steam shovel, the gravel, largely cemented, is pulverized and screened by the machine and the fines are elevated and run over the Stebbins tables, which use air instead of water as a medium of concentration. The claim is made that a plant that will treat 300 to 400 tons per day of 9 hours costs $12,000, exclusive of the digging machinery. The author has yet to learn that any of these machines using air as a means of concentration has proved successful.

DREDGING OPERATIONS.

Dredging operations are adequately described in Mr. Jennings's paper. Dredging costs vary in different districts according to conditions encountered and the methods of calculation employed, and even in the same district and under the same management dredges of similar size and design or the same dredge in different parts of the same property will show a wide difference in operating cost owing to the character of the ground dug.

DREDGING IN UNITED STATES.

The largest dredging company in the world, the Natomas Consolidated, of California, operated 13 dredges in 1914 and handled 25,850,000 cubic yards at a total cost of 5.8 cents per yard. To show the wide differences in dredging costs of dredges operating under the same management the following is given: One dredge for the year above mentioned handled nearly 2,000,000 yards, at a cost of 2.5 cents, and another dredge handled over 2,000,000 yards, at a cost of 7.14 cents, differences in the depth and the character of gravel causing the difference in cost. The power cost of the first dredge was 0.6 cent per yard and that of the second 1.32 cents, with other cost details also differing greatly.

The ten dredges of the Yuba Consolidated at Marysville, Cal., handled a total of 17,000,000 yards at a cost of 4.40 cents, varying from 3.29 to 6.86 cents a yard, according to the dredge and conditions of operation and repairs. The dredge charged with the higher cost underwent reconstruction which was charged to the yearly operations of 1914.

In Montana, as described in Mr. Jennings's paper, the cost of handling a total yardage to July 31, 1915—more than 32,000,000 yards—was 5.91 cents a cubic yard. With indirect expenses of 1.05 cents, the total cost was 6.96 cents a yard. Operating costs for different dredges for the total period mentioned varied, according to the size and the type of dredge and to operating conditions, from 4.85 to 6.94 cents a cubic yard.

In Colorado, the dredges of one company handled, in 1914, 3,000,000 yards at a cost of 5.9 cents a yard. One of the dredges in Idaho handled 4,670,000 yards for the same year at a total cost of 2.77 cents. The yardage mentioned is the record for any single dredge in the world. Other dredges operating in the United States obtain costs according to conditions of operations, size of boat, etc., varying from 5 to 10 cents a yard.

DREDGING IN SOUTH AMERICA.

In South America, the Pato dredge in Colombia for the year ended September 30, 1914, handled 920,000 cubic yards, at an operating cost of 18.4 cents, which, with general and office expenses, brought the total expenditures to 23.2 cents per cubic yard. For the year ended September 30, 1915, the operating cost was estimated at 16 cents a yard and the yardage handled was considerably in excess of that for the previous year, 1,420,000 cubic yards being handled. This dredge is equipped with 8-foot buckets, and the operating conditions were not considered as being unfavorable for a tropical country when the dredge was built.

DREDGING IN THE PHILIPPINE ISLANDS.

Dredging costs in the Philippine Islands have been greatly under those mentioned above. The work of the Gumaos dredge is given in detail in Mineral Resources of the Philippine Islands.[a] This is a 5-foot dredge and has handled during 27 months of operation, from October 1, 1912, to December 21, 1914, a total of 1,850,000 cubic yards, at a cost of about 12 cents per cubic yard.

DREDGING IN ALASKA.

To go from the Tropics to the far north is rather a radical change, but the operating costs in the far north are in excess of those in the Tropics on account of shorter seasons, frozen ground, and various other operating and economic difficulties.

The costs of the various dredges of the Yukon Gold Co. for the year 1913 varied from 21.16 to 33.79 cents per yard, the highest cost for thawing being given as 18.36 cents. Approximately 75 per cent of the gravel is frozen.

Dredging costs in Alaska may be said to vary from 20 to 30 cents a yard, though in some instances a much lower operating cost is claimed. However, in all instances coming under the writer's observation, the actual cost has not been less than the first figure given.

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[a] Eddingfield, F. T., The Paracale district: Mineral Resources of the Philippine Islands for 1913, Bureau of Science, 1914, p. 10; Pratt, W. E., Gold mining in the various districts in 1914: Mineral Resources of the Philippine Islands for 1914, Bureau of Science, 1915, p. 15.

DIPPER DREDGES.

The dipper dredge was formerly operated with some success in different fields, and a dipper dredge formerly operated in the Oroville district has just been rebuilt in northern California. This type of machine does not meet with the approval of dredge operators, and its efficiency, both as an excavator and as a gold saver, can not be compared with the modern dredge.

CLAMSHELL BUCKET DREDGES.

The clamshell bucket on a dredge or on dry-land excavation has been a failure in placer-mining operation, though machines of this type were tried as early as 1887 in California and at later dates in Montana and Colorado. Wrecks of machines of this type can be seen at Breckenridge, Colo., and at Ruby, Mont. The clamshell dredge as used on river and harbor work is, of course, a successful excavator, and the loose-fitting leaves of the bucket, permitting an escape of water, constitute a decided advantage in the harbor work, where in gold dredging the fine material and some gold would be lost with such equipment. The clamshell bucket is a poor excavator in hard ground, as it must penetrate the ground by force of weight alone.

SUCTION DREDGES.

The suction dredge proper has never been a success in gold dredging. A plant that is sometimes confused with the suction dredge, but is of widely different design, is the so-called pump dredge.

CENTRIFUGAL-PUMP DREDGES.

The centrifugal-pump dredge is built on a pontoon, which rests on dry land while the dredge is working, though it can be floated and moved to a new position if enough water is available for a flotation pond. The equipment consists of a centrifugal pump for supplying a hydraulic nozzle, if water under pressure is not available, and a second pump for elevating the gravel to the sluices after it has been washed to a sump in front of the dredge by the hydraulic giant. The sluices are placed either above the dredge or at a convenient point on the bank.

The quantity of water required varies under different conditions, but it has been estimated that a minimum of 2,500 gallons is necessary for each cubic yard to be raised by the pump. The excess water can be returned to the pond and reused. More than twice as many men are required as are necessary on a bucket dredge, and power costs are generally high. Although lower costs are reported from some countries where cheap labor is obtainable, the total operating cost for a plant of this type can be roughly approximated at 25 cents a cubic yard.

DREDGING AT THE PANAMA CANAL.

A paper on placer-mining costs at this time would seem incomplete without some reference being made to the work at the Panama Canal.

According to W. G. Comber, in a paper on dredging in the Panama Canal, presented at a meeting of the International Engineers' Congress, San Francisco, September, 1915, the grand total quantity of material removed from the Panama Canal and auxiliary works by dredging from 1905 to December, 1914, was 115,700,000 cubic yards. The total cost per cubic yard was 26.77 cents, including the work of ladder, dipper, and suction dredges and the total cost of operation, maintenance, material, plant, and administration.

Considerable interest has been shown by gold-dredging operators in the performance of the large bucket ladder dredge equipped with two lines of buckets, one having a capacity of 1 cubic yard and the other of 2 cubic yards. The bucket lines are interchangeable, one being used for heavy digging and the other where the work was lighter. The total material handled by this dredge from April, 1912, to January, 1915, is given at 3,351,600 cubic yards, and the cost at 36.59 cents per yard.

In excavating the canal the material from bucket, dipper, and sea-going suction dredges was delivered to barges and hauled 4 to 10 miles to a permanent dump. The intermittent nature of the work and the long haul account in a measure for the high operating cost. Although comparisons between the work of these dredges and those operating in different placer fields is, of course, futile, most gold-dredge operators will have a feeling of satisfaction when they consider these figures in connection with the operating costs of their own machines.

IMPORTANCE OF MAKING TESTS PRELIMINARY TO DEVELOPMENT OF PLACER GROUND.

It is realized that some mention should be made of the importance of making a thorough examination of placer ground before commencing to work it. This need is too important a subject to be discussed in the space available, but it may be said that a sufficient mineral content, conditions assuring economic operation, and sufficient auriferous ground are necessary to warrant any project. Most failures in placer mining, as in other branches of the mining industry, are due to the fact that a thorough examination by competent engineers is not made in the first instance. Although there is little excuse for such mistakes in the future, it is to be expected that some operators will, as in the past, prefer to "go it blind" or to be content with incompetent advice.

PUBLICATIONS ON MINERAL TECHNOLOGY.

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